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Development of a Tool for Assessing the Degree of Automation and Integration on Capital Projects

by

Keith Allen Welch, B.S.

Thesis

Presented to the Faculty of the Graduate School of

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Development of a Tool for Assessing the Degree of Automation and Integration on Capital Projects

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Dedication

This work is dedicated to my loving wife Sandra and our beautiful daughter Valerie. They both displayed extraordinary patience throughout and I could not have done it without them.

"God, grant me the serenity to accept the things I cannot change, courage to change the things I can, and the wisdom to know the difference" – Catholic Serenity Prayer

Abstract

Development of a Tool for Assessing the Degree of Automation and Integration on Capital Projects

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The University of Texas at Austin, 1998

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The goal of the Fully Integrated and Automated Project Processes (FIAPP) research thrust at the University of Texas at Austin is to improve the industry through better utilization of integration and automation technologies. This thesis describes the first step toward that goal: development of a survey with which to measure both the degree of technology use on projects and the implications of such usage on project outcomes. Also included in this report, is guidance for future researchers who wish to develop similar surveys or gather similar data.

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

Despite the similarities between construction and manufacturing, the construction industry has traditionally lagged behind the manufacturing sector in its usage technology. Some unique characteristics of the capital facility deliver process have been cited by many in the construction industry to explain the technological disparity between the to industries:

- The uniqueness of construction projects versus the relative stability of manufacturing processes.
- The volatility of project teams in construction in contrast to consistent manufacturing workforces.
- The unpredictability of the outdoor work environment characteristic of construction sites compared to the invariability of the indoor manufacturing environment.

Recently, however, the construction industry has seen profit margins shrink and project schedules get more condensed. In an attempt to deal with these pressures, new, more complex project delivery methods such as "Design/Build" and "Fast-Tack" have been developed. With these new delivery methods has come a greater need for coordination and communication between all the project participants. This increased demand for communication has forced construction companies to turn to information technology just to remain competitive. A recent study of architectural principals found that 94% said collaboration throughout the construction life-cycle was "their primary automation goal over the next 5 years." The same study noted that 82% of those principals had gotten pressure from project owners who wanted engineering information integrated into their own

databases to support facility maintenance and repair activities in the future. (Thornbury 1998)

Although most agree that integration and coordination, through the use of technology, is important, very little quantitative data is available to help company executives decide which applications of technology will contribute most to the success of their capital facility projects and, by inference, to their company's bottom line.

The Fully Integrated and Automated Project Processes (FIAPP) research thrust being conducted at the University of Texas at Austin and funded by the Alfred P. Sloan Foundation is seeking to provide that quantitative data.

In 1990 the Alfred P. Sloan Foundation began sponsoring Centers at major U.S. universities devoted to the study of particular industries. In 1996, the University of Texas received funding to establish the "Sloan Program for the Construction Industry." The FIAPP research thrust is part of the overall Sloan Program at UT Austin and FIAPP, in turn is comprised of several research focus areas:

- Industry Automation and Integration Metrics.
- Enterprise Resource Planning (ERP) Systems and Capital Facility Delivery.
- Success Case Studies in Capital Facility Automation and Integration.
- FIAPP Standards Development, Accomplishments, and Plans.

1.1 OBJECTIVES

As with most Sloan-sponsored Industry Study Centers, the objectives of the Sloan Program at UT are to:

- Develop an understanding of the issues most important to companies in the industry.
- Consider the industry on a worldwide basis in order to compare U.S. companies with their foreign counterparts.
- Contribute independent third-party evaluations and analyses of the industry.
- Take the experience gained from industry study back into the classroom.

The goals of the FIAPP research thrust are to:

- Promote the advancement of seamless capital facility delivery and operations work processes.
- Explore the breadth of life-cycle integration opportunities from emerging communication and computing technologies.

This report discusses the first step the Metrics study team took toward these goals. The objectives of this portion of the study are to:

- Develop a tool to measure the use of automation and integration technologies in the construction industry.
- Test the tool in a pilot data-gathering effort and document lessons-learned from the pilot data-gathering effort that will guide the efforts of future researchers.

1.2 SCOPE LIMITATIONS

This report covers the development of the data-gathering tool only. Development of the metric, data analysis, and results will be presented by others.

The study covers the building, infrastructure, and industrial sectors of the industry. However, the single-family residential sub-sector, involving small builders, is deliberately neglected. Within these sectors, owners, designers, general contractors, design/build contractors, subcontractors, and suppliers are all targeted.

1.3 STRUCTURE OF REPORT

The report begins with some background concerning the state of technology in the industry and elaborates on the motivation for the FIAPP metrics study. Once the motivation for the study is established, Chapter Three explains the process used by the research team to develop, test, and refine the survey form. Then Chapter Four presents the output of that process: the survey form. Key parts of the survey form are discussed with commentary that has been distilled from the pilot data-gathering effort. The commentary is intended to answer some of the most common questions about the survey that future researchers are likely to face during the conduct of data-gathering interviews. Finally, Chapter Five offers conclusions and some guidance for future research efforts as well. The appendices contain copies of the three versions of the survey mentioned in Chapter Three, documentation of the changes made between versions 2.0 and 2.1 and between versions 2.1 and 2.2, as well as a detailed listing of automation and integration technologies.

Chapter 2 Background

The purpose of this chapter is to provide a basic understanding of the current status of technology use in the construction industry and to explain the elements required to create a metric that will measure technology use on capital facility projects.

2.1 OVERVIEW OF PROJECT INTEGRATION AND AUTOMATION TECHNOLOGIES

Many technologies that show great promise for application to the construction industry are currently available or just over the horizon. This section discusses some of the base technologies that form the building blocks of more sophisticated systems. Then some benchmark technologies that are currently available are discussed. Readers should note that this is only a sample of the technologies available. A more complete list is included in Appendix G.

2.1.1 Base Technologies

Machine Vision

Machine vision is a base technology that converts analog images into a digital form that computers can understand and manipulate. Its applications range from something so commonplace today as scanning a document or a bar code, to complex optical sensors that allow robots to navigate a construction site. In effect, machine vision gives a computer eyes.

Natural Language Processing

Natural language processing is similar to machine vision except that it digitizes sound rather than images. It could be useful in situations where a worker's hands or eyes are busy. For example, while conducting a quantity survey or a site inspection, the user can concentrate on the task and speak naturally without looking at the computer as it dutifully records every word or executes the appropriate commands. If machine vision gives a computer eyes, natural language processing gives it ears.

Object Oriented Programming

Machine vision and natural language processing allow automation of the data input process. Once that data is in digital form it must be stored and manipulated. Object-oriented programming (OOP) is a relatively recent paradigm for the representation and storage of data that has already done much to change the way businesses operate. The advantages of object-oriented programming for the construction industry are shown below. (Chin et al 1997)

- Greater reusability of code [and designs]
- A friendlier, [more intuitive] user interface
- Greater flexibility to react to rapid changes in requirements

Objects interact through simple messages passed from one object to the other that tell the receiving object to modify one of its attributes (e.g. operator to forklift: "move forward"). It is through standardization of the phrasing of these simple messages, that objects get their portability: "A message, phrased in a

simple and standardized way, is independent of how and where the object is implemented." (Ibid.)

The easiest application to visualize in a construction context is the use of objects in a 3D or 4D (3D plus time) modeling environment. If individual structural elements were treated as objects, attributes such as material composition, weight, color, and support requirements could be stored in an attributes database and linked to the graphical representation of that object. When the object is subsequently manipulated the model would behave in an intuitive manner consistent with its attributes and its interaction with all the other objects in the system.

The Center for Integrated Facility Engineering (CIFE) at Stanford University is developing just such a system that analyzes a 4D building model to ensure it has adequate temporary structural support during erection. The research is still in its infancy, but its implications for the design process are obviously vast. (McKinney and Fischer 1997)

2.1.2 Current Technology Applications

Construction Robotics

Object-oriented programming is also being used to assemble control programs for construction robots. Researchers first attempted to apply robotic technologies to construction tasks in the early 1980's. At that time robots were found only in factories where they performed simple, rigidly structured tasks from a stationary position. (Haas et al 1995)

However, as computers have become more powerful and less expensive, the robots, using those computers have become, smarter, stronger, more sensitive, and consequently, more feasible for construction applications than their predecessors.

Some of the major technologies that have been successfully implemented in construction are: (Ibid.)

- Laser guided grading and leveling
- Tipping and proximity sensors
- Automated painting and sandblasting
- Advanced tunneling techniques

Other technologies that are in development and show promise for application to capital projects include: (Ibid.)

- Autonomous off-road hauling vehicles
- Automated inspection
- Robotic sheet rock manipulators

Despite these advances, there remains little real penetration at the site level; and certainly no sign of the development of the extensive information infrastructure necessary to support significant levels of site automation and robotics. (Bradley 1997)

The Internet

The Internet may eventually prove to be that infrastructure, however it is still relatively new and most construction companies are only now beginning to

see its implications to their businesses. Design firms seem to have taken an early interest in this new technology, with 20% of the computers in an average design firm having web browser software installed compared to the industry average 11%. Also, 42% of design firms have created at least one project-specific Web site, versus only 19% of the industry as a whole. (Phair and Angelo 1997)

Project Web sites

Project-specific web sites are a recent use of the Internet that allows geographically separated team members to operate with a higher degree of integration. They are also proving to be an excellent public relations resource since the public has greater access to project information.

The following are some examples of available web-based information from vendors Blue-Line/ On-Line, Evolv, and MPInteractive.

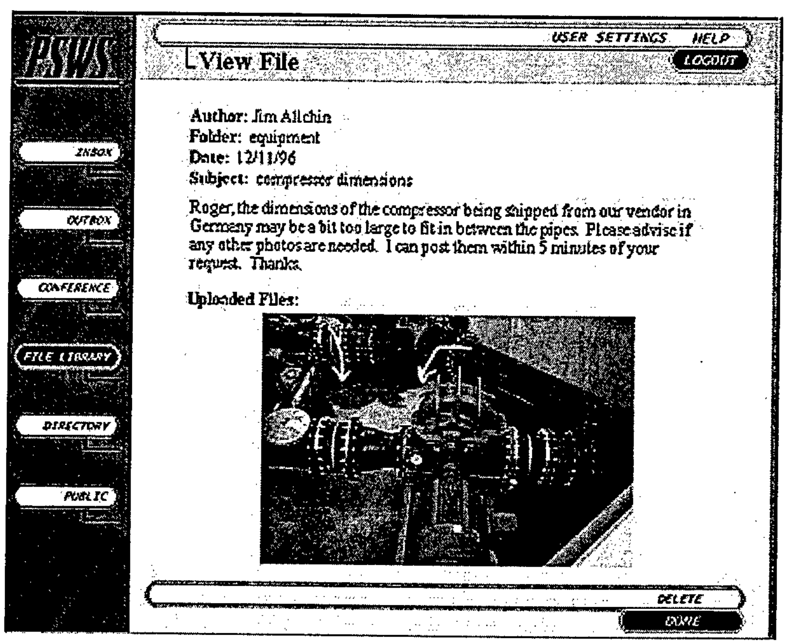

Figure 2.1 Blue Line On-Line's ProjectNet – Progress Photos

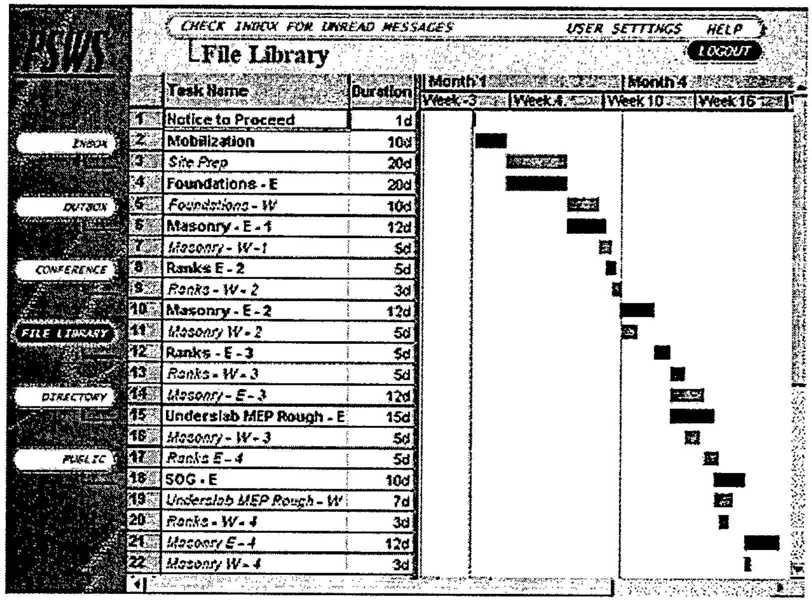

Figure 2.2 Blue Line On-Line's Project Net – Schedule Screen

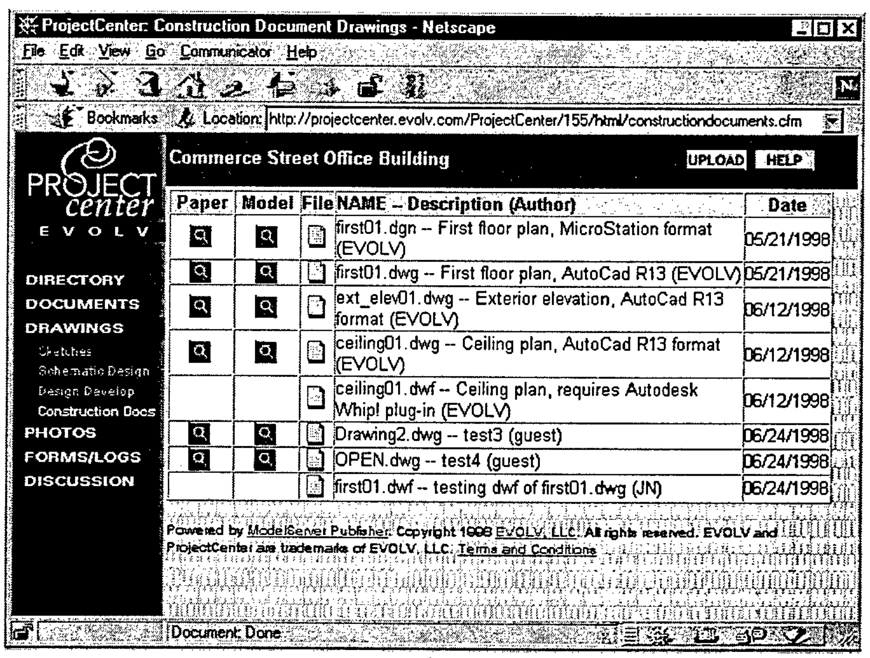

Figure 2.3 Evolv's ProjectCenter – Drawing List

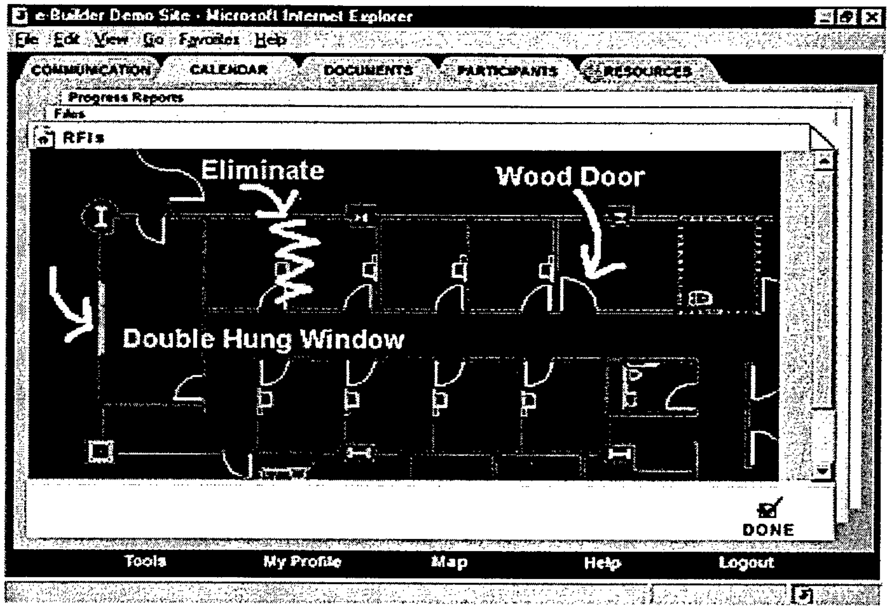

Figure 2.4 MPInteractive's eBuilder – Collaboration Example

Web-based Collaborative Design

Through these project web sites, project teams practice something called "virtual teaming." It is a technique that allows project team members from all over the world to connect over a secure network that uses the Internet. They track design and construction progress and share project information such as drawings, still pictures, and even full-motion video.

Electronic whiteboarding and electronic redlining are less expensive technologies that also allow geographically diverse team members to collaborate without the delays and high costs of frequent travel. Both technologies allow multiple users to comment on and modify a single electronic copy of a document. The difference is that whiteboarding allows simultaneous, real-time interaction,

whereas a redlined document must be electronically transmitted from user to user in turn. (Thornbury 1998)

Electronic Data Interchange

Electronic Data Interchange (EDI) does not improve collaboration, but it does improve communication efficiency by ensuring all parties to a transaction are speaking the same electronic "language." And since the language is the same, data can be transferred from one company to another without having to be re-entered even if both companies use different software applications.

As of February 1993, approximately 6,000 companies in various industries were using this new technology to reduce paperwork and improve the accuracy of data throughout the materials management process. (CII 1993 Publication 20-1)

In the EDI process the sending computer uses simple translation software to convert a document into standard American National Standards Institute (ANSI) format before it is transmitted to the recipient. The receiving computer then uses a similar translation program to convert the ANSI format into a format that it can read. Since the translation software does all the work there is no need for a human to re-enter the information from a paper document. So both paper and human error are eliminated from the transaction.

Enterprise Resource Planning Software

Enterprise resource planning (ERP) software, often called enterprise-application software, is a bundle of software modules that, when combined, create a comprehensive management package that integrates all of a company's operations from order taking, to inventory control, to manpower and accounting.

In the early 1990's a "client-server" revolution took place in the computer network world that made ERP very attractive to many businesses. (Edmondson et al 1997)

The integrated nature of the package ensures that a change or addition to data in one module is reflected in all others and warnings are issued if problems arise. For instance, if a construction company had an ERP system, a change order to install 2,000 more lineal feet of sewer pipe would trigger checks of the on-site inventory of pipe and of manpower. The respective managers would be notified and any shortage would activate a warning to buy, or hire more.

Currently the system focuses mainly on manufacturing processes, but modules are being created and adapted for use in the construction industry.

2.2 PREVIOUS TECHNOLOGY SURVEYS BY OTHERS

The technologies described above are a few of the more sophisticated options available. But how sophisticated is the construction industry in its use of computers? A couple of recent studies have attempted to answer that question.

2.2.1 ENR Survey

In January 1997, *Engineering News Record* (ENR) magazine contracted with Rose Research of Stanford, Connecticut to conduct extensive telephone interviews with the decision-makers of 300 firms including designers, general contractors, and specialty contractors.

Their survey was intended to measure trends in corporate strategies toward the implementation of information technology programs. They asked what

hardware and software systems they were using, what investment they made – and are intending to make in the future – in IT, and how they use the Internet.

The results showed that companies seem to be warming up slowly to the impact of IT. E-mail is being more widely used, and some are even experimenting with project web pages.

However, there is still a lot of old hardware out there that companies are working hard to bring up to date. For example, 33% of respondents maintain a minicomputer and 50% have machines with sub-Pentium processors. (Phair and Angelo 1997) Many firms understand the need to maintain currency, but most are finding it hard to obtain the money to realize that vision. Large companies are typically hardest hit by this challenge since the technology is usually out of date by the time they upgrade hundreds, or even thousands, of machines.

While keeping hardware current is important, connecting existing hardware components is probably most important. Joseph Riedel, president of Beers Construction in Atlanta said, "It's not about a better, more powerful computer, but the amount of interconnectivity between the person on the keyboard and everybody else." (Ibid.) The survey shows 75% of companies have local area networks (LANs), whereas only 20% report setting up inter-office, wide area networks (WANs), and 50% of respondents reported having machines with e-mail capability. Barry Millikan, systems director at Parsons Brinkeroff in New York City, felt that e-mail was "...more than just an alternative to the telephone." He said, "As a manager I have a record of every communication made. And I can easily send a message to 10 people. Doing that by phone or fax

is laborious. And I know I make many fewer long distance calls than I used to." (Ibid.)

2.2.2 The American Institute of Architects Survey

Also in 1997, the AIA surveyed more than 2000 of its members to ascertain their use of the Internet. They found that 90% of firms with 10 or more employees are connected to the Internet. (Post 1997) The survey found that architects are using the Internet for many purposes. They used it for:

- Marketing
- Project scheduling
- Tracking job leads
- Recruiting staff
- Gathering product information
- Researching clients
- Communicating with project team members

Paul Collart, a principal at Technisis, says, "Traditionally, through the design and construction process, so much information is lost when we transfer from industry to industry – from architect to mechanical engineer to contractor. The idea is to not lose information between fields. The Internet is a way to do this and to capture all that knowledge." (Ibid.)

2.3 PROJECT VS. ORGANIZATION BASIS

The two studies highlighted above make qualitative assessments of the use of computers in construction. These studies used telephone interviews for the

most part to gather their data, and their results were presented from the perspective of the company and its overall information technology strategy. This approach offered a good overview of the industry-wide attitude toward computers and some examples of the most heavily used and most promising technologies. From the point of view of this study however, these studies did not provide the all-important link to project performance that would allow companies to see for themselves whether the technologies were indeed promising or just expensive experiments.

For this reason, the project team decided to focus its efforts on acquiring project-centered data that could ultimately be used to link specific technology implementations to project success measures.

Since one of the objectives of this research is to determine the industry's progress toward an integrated data environment, an approach that cuts across phase boundaries and corporate boundaries was seen as advantageous. A project-focused approach does just that.

2.4 STRUCTURED VS. OPEN-ENDED QUESTIONING

Another important question faced by the research team early on was what sort of approach should be used to gather data. The two options under consideration were a specific, task-centered survey or open-ended, scenario-based interviews.

The interview approach offered some distinct advantages over the survey method, but it also held some fairly serious disadvantages that were hard to overcome. The advantages stemmed from the inherent two-way communication

of face-to-face and even telephone interviews. The subject would be more inclined to participate in the study. The subject would have a better understanding of the questions as the result of clarifying dialog and, as a consequence, the answers might be more meaningful. In addition, the research team would get a better understanding of the subject's work processes through adaptive questioning than through a rigid set of pre-arranged questions.

The problem with open-ended, adaptive questioning is that it makes data comparison impossible from project to project or across industry sectors. In order to do a comparative study it is important to have a common, structured set of questions to ensure the scope and coverage of the study remain fixed.

The team decided to use a structured survey because the survey would ensure comparability of the data, from project to project, that scenario-based interviews could not offer. The survey can be administered in a number of different ways: by phone, by fax, e-mail, or in person. However, the questions always remain the same.

2.5 DEFINITION OF A METRIC

Apart from deciding on the focus and structure of the data gathering process, the foremost objective of this study is the development of a metric that measures the degree of technological sophistication – particularly relating to information technology – used over the life-cycle of capital projects. Consequently, the research team had to keep the attributes of a good metric in mind:

- Is it accepted as meaningful to the customer?
- Does it tell how well an organization's processes and tasks fulfill its goals and objectives?
- Is it simple, logical, understandable, and repeatable?
- Does it show a trend?
- Is it unambiguously defined?
- Is the data economical to collect?
- Is it timely?
- Does it drive the appropriate action?

2.8 TYPES OF DATA TO COLLECT

Before discussing development of the survey tool and the data gathering process it is important to understand what types of data to collect. The two categories of data needed are 1) Characterization data and 2) Assessment data. Table 2.1 shows a list of the types of required under each category:

Table 2.1 Types of Data to Collect

Data Type	Category
Company Information	Characterization
Project Information	Characterization
Respondent Information	Characterization
Degree of Automation	Assessment
Degree of Integration	Assessment
Project Performance	Assessment

The characterization data helps ensure the sample is representative of the whole population of construction company and project types. It also facilitates the comparison of assessment data by industry sector, project size, etc.

The assessment data is the heart of the metric. The automation assessment measures the sophistication of the technology used to accomplish individual tasks in the capital facility delivery process, while the integration assessment measures the sophistication of technology used to transfer information between tasks. These assessments, in conjunction with the characterization data, help determine the state of technology in the industry at any given point in time as well as to show trends over time.

The project performance assessments help link the other two technology assessments of a given project to the outcome of that particular project. With this link, researchers can draw conclusions about which tasks and which links offer the greatest potential to improve project performance if they are automated.

Chapter 3 Study Methodology

This chapter explains the methods used by the research team for developing a data collection tool with which to measure the degree of automation and integration practiced during the life-cycle of typical capital projects.

Much of the examination concerns development of a list of tasks typical and fundamental to the wide variety of capital project types. The listing had to be broadly applicable in order to represent the construction industry as a whole. A competing interest of the research team was to keep that list to a manageable size that captured the essence of a construction project without becoming a burden to the respondents who fill out the survey. The aim was to have industry professionals rate each task, as it was accomplished on their project, in terms of its use of automation and integration technologies.

Following development of the list, the next important step was to define a rating scale that clearly described the spectrum from a completely manual task to one that is accomplished almost exclusively by a computer (or computerized tool) in an integrated data environment. The definitions of each increment on the scale are very important to the accuracy of the resultant data. Accordingly, some explanation of those definitions is also covered in this chapter.

Once the task list was complete and the rating scale was clear, the first version of the survey was all but complete. It was time to start locating industry subjects that were willing to review the survey with a critical eye and provide some sincere, constructive feedback on its content and approach. This feedback

formed the basis for a second version of the survey that was more concise, clearer, and infinitely more useful than its predecessor. There is some examination of the problems with the first version of the survey and how those problems were solved while developing the second version.

Figure 3.1 is a flowchart graphically depicting the major steps in the process used to develop the survey and gather data. Given this overview, the rest of this chapter will examine, in more detail, each block of the flowchart in turn.

3.1 DEVELOPMENT OF STUDY OBJECTIVES

The Metrics focus area study supports the Sloan Program FIAPP Thrust Area. Consequently, the study team developed the following objectives to support the larger FIAPP effort:

- Develop a tool for measuring automation and integration on capital facility projects.
- Link automation and integration technology usage with project outcomes.

Both of these objectives together "promote the development of a seamless project delivery process," which is one major goal of the FIAPP Thrust Area as a whole.

3.2 PROPOSAL OF TASKS AND INTEGRATION LINKS

The research team began developing the survey tool by generating a list of tasks typical of the capital facility delivery process. The purpose of the listing process was to find a sample of tasks that were so fundamental that they applied

to almost all kinds of projects. In addition, the tasks had to represent the entire project life-cycle. Later, the listing would be combined with an automation

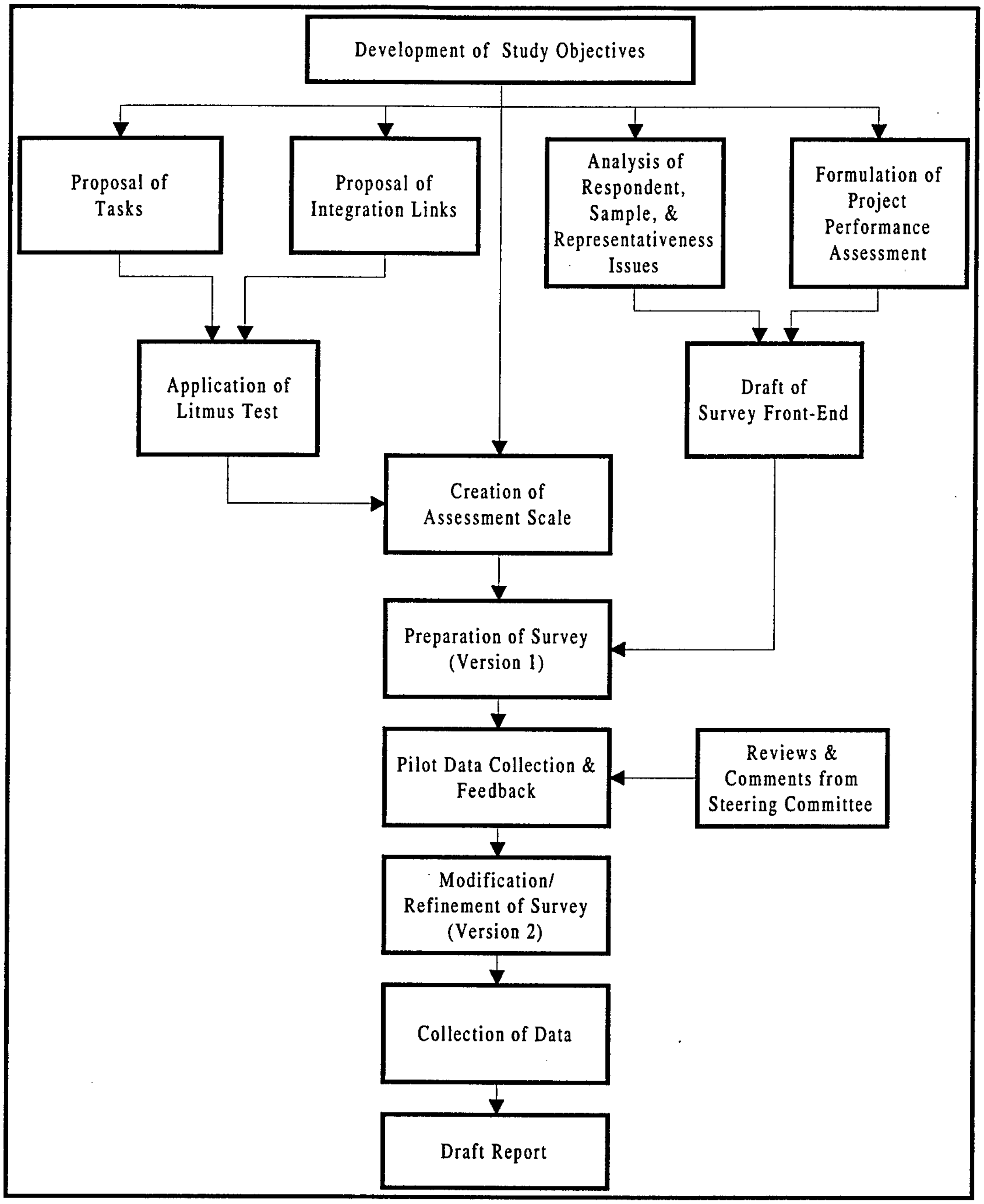

Figure 3.1 Data Collection Tool Development Flowchart

assessment scale, allowing a respondent to assess how automated each task was on a particular project.

The listing of tasks formed the basis for an assessment of the degree of single-task automation, but offered little insight into how those individual tasks were integrated into a "seamless project delivery process."

Consequently, the research team developed the concept of an "integration link" to describe the exchange of information from task to task. The link could be *inter-disciplinary* such as the link between mechanical pipe routing and the structural system layout. It could be *inter-organizational* such as the link between design changes and the builder's short-run schedule. It could even be *a link across time* such as lessons-learned following a major heavy lift that are subsequently used to improve future projects.

The concept of an integration link is presented graphically in figure 3.3:

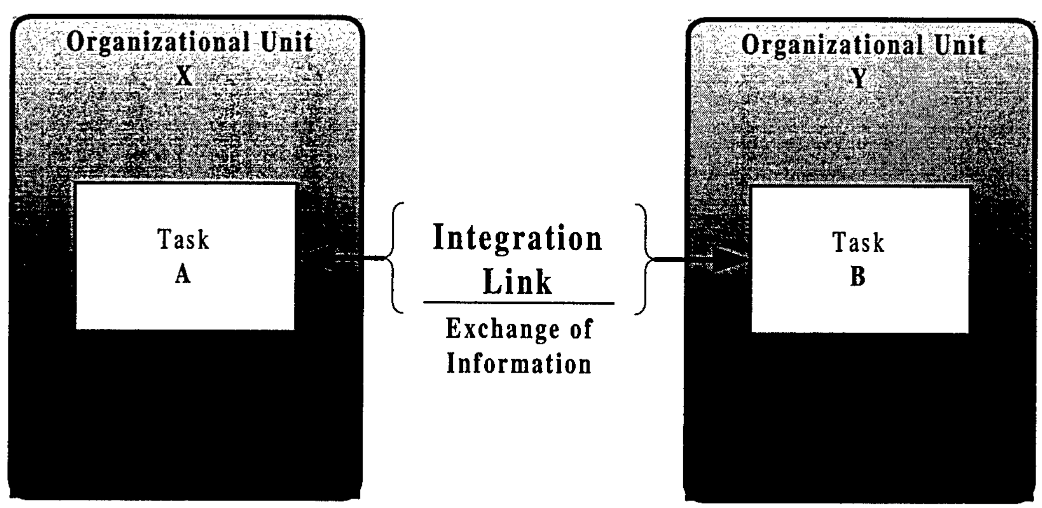

Figure 3.2 Concept of an Integration Link

Keeping the integration link concept in mind, the research team set about generating a sample listing of integration links that are fundamental to the project delivery process and that complement the task listing. This list of integration links in combination with the automation assessment scale gives researchers a means to measure how automated the integration links are within a particular project.

A manual integration link is similar to a manual task. The transfer of information across a completely manual link involves a human being physically transporting acquired knowledge or paper documents from one place to another. A slightly more sophisticated link could involve basic electronic tools like a telephone or a facsimile machine. On the other hand, a completely automatic link allows seamless data transfer with no requirement for human intervention. The transfer of data via floppy disks or compact disks could be thought of as a rudimentary form of electronic link since it avoids the problem of re-entering data on the receiving computer even though the disk must still be physically transported to its destination.

It should be clear from the preceding discussion of manual versus automatic links that an automatic link presupposes the existence of "islands of automation," or tasks that have been at least partially automated. For example, it makes little sense for data to be transferred over the Internet or via floppy disk if the task at the receiving end is still accomplished by a person using pencil and paper. Therefore, it is apparent that the process of achieving integration

throughout the project life-cycle is an evolutionary one. Figure 3.4 is a depiction of this evolutionary process that has been adapted from some early work on integration conducted by the Construction Industry Institute:

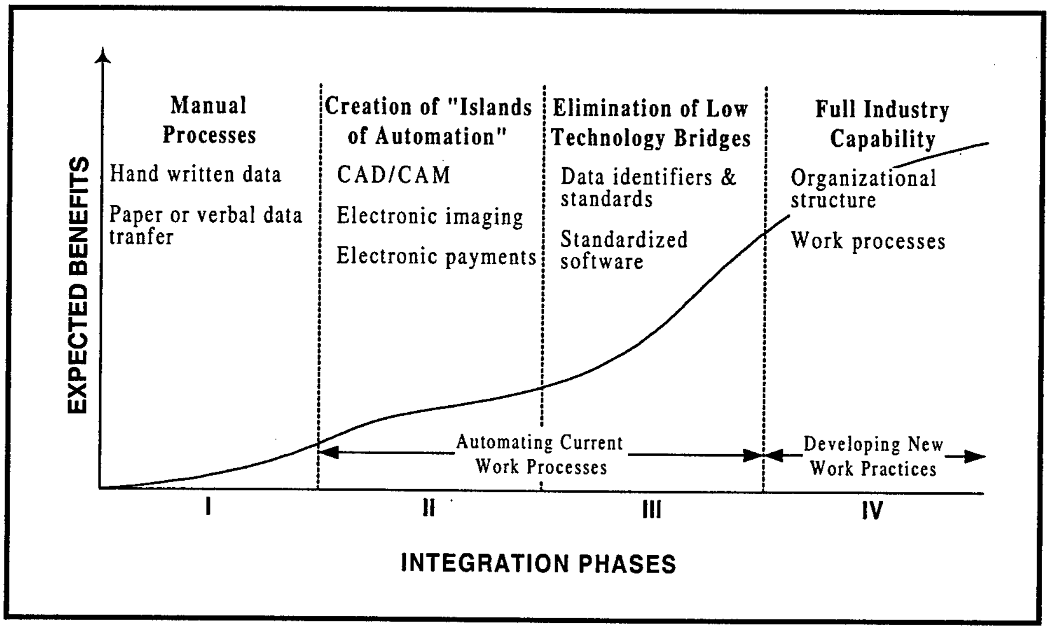

Figure 3.3 Evolution of Full Data Integration (CII 1993 publication 20-3)

3.3 APPLICATION OF LITMUS TEST

The original listing of tasks and integration links, that resulted from both brainstorming and a literature search, contained over 200 items. This number was clearly too long to allow a respondent to complete the survey in a reasonable time (considered to be 30 minutes by the project team). So the team developed a systematic means for eliminating some of the less important tasks. This process was labeled "the litmus test" and it is illustrated in Figure 3.5 below.

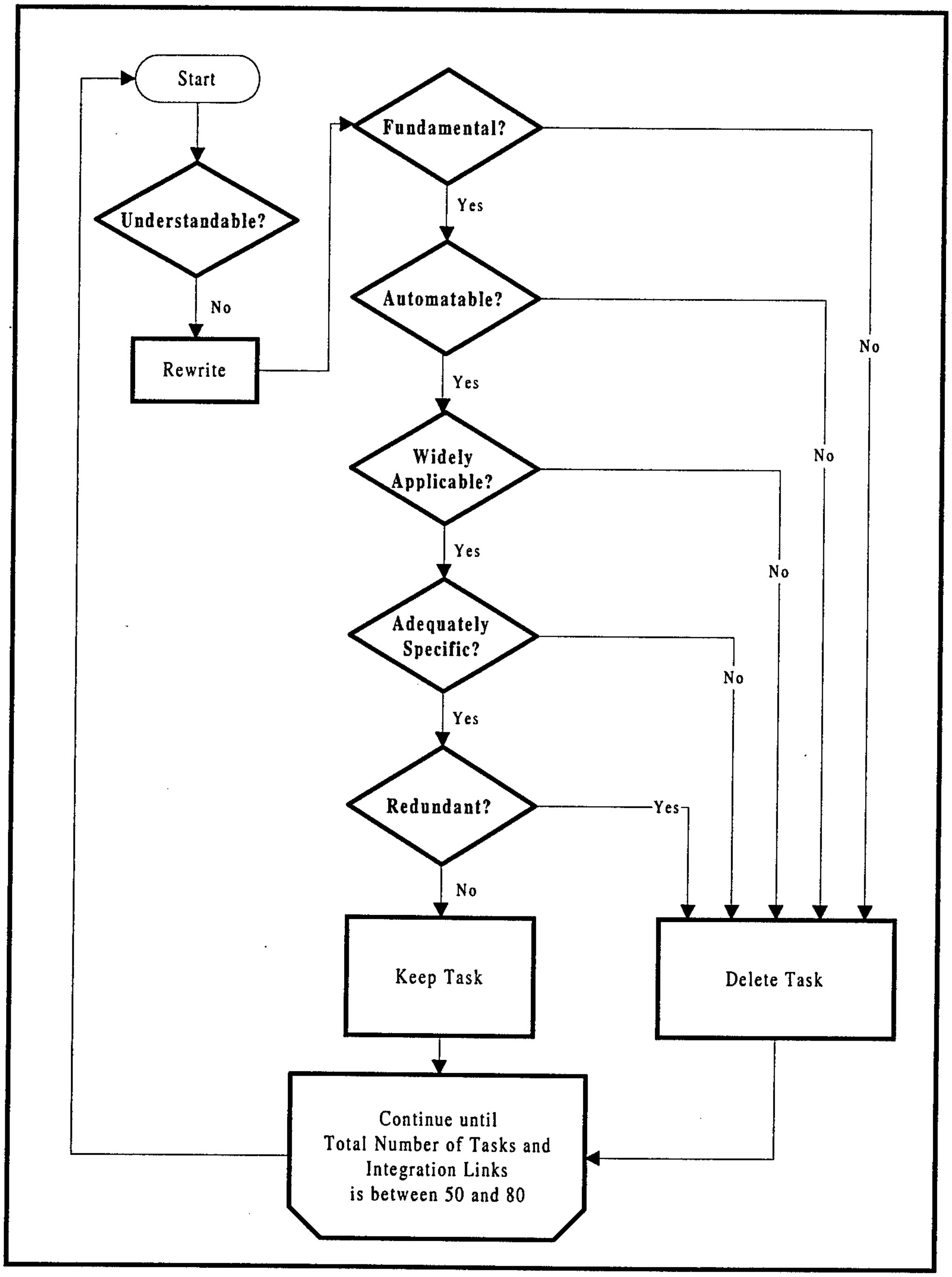

Figure 3.4 Litmus Test Process

The list was initially reviewed to ensure the wording of each item was clear. Any that were deemed confusing were reworded before the litmus test continued.

Each item was then tested to ensure it was fundamental to the project delivery process. This test was important for two reasons. First, the item had to have enough potential to impact project success to warrant its assessment. Second, the task or link had to be so central to the completion of a project that it will be performed for many years to come. Otherwise, the survey will lose its usefulness in a short time.

Each item also had to have sufficient potential to be automated. An example of such a task is the development of project objectives. The team considered human interaction and decision-making so critical to the process of developing objectives that the potential for automation seemed relatively small so that task was excluded from the list.

Each task and link also had to be applicable to the whole spectrum of project types and industry sectors to ensure the results of the study are widely comparable. So any tasks that related to a limited range of project types were eliminated.

Specificity of scope was a challenging issue. Each item on the list had to be specific enough to make the assessment meaningful. For example, an assessment of degree of automation used to accomplish "the design process" would be of little meaning since the process is so complex. In addition, the

phrasing of the task or link could not suggest a specific technology paradigm because doing so might jeopardize the longevity of the survey. To illustrate the point, consider design drawings. The current technology paradigm for preparing drawings is Computer-Aided Design (CAD). If another technology supplanted the CAD paradigm at some point in the future, any assessment relating to CAD would be obsolete.

Finally the list was reviewed for redundancy. Any items that had already been addressed or nearly so elsewhere were eliminated.

Once the listings of tasks and links were complete, each was organized into the following chronological project phases:

1. Market Research/ Needs Analysis; Project Definition/ Programming
2. Conceptual Design & Feasibility/ Schematic Design
3. Front-End Engineering/ Design Development
4. Detail Design/ Working Drawings
5. Procurement/ Long-Lead Procurement/ Owner-Furnished Equipment
6. Construction
7. Start-up/ Commissioning
8. Operations & Maintenance
9. Dismantlement

The words used to describe each phase were chosen carefully in order to appeal to the widest possible audience. For example, participants on industrial projects typically use the term "Front-End Engineering," whereas participants on building projects use the term "Design Development". Many alternative

wordings were included to ensure that most respondents would understand the terminology.

As discussed later, the nine phases listed above were ultimately combined into the six phases found on the version 2.0 and higher surveys.

3.4 CREATING AN ASSESSMENT SCALE

The one step remaining that would transform these simple lists into real questions was the development of an assessment scale. A numeric scale from 1 to 5 was originally chosen to represent the continuum from completely manual to completely automated. Table 3.1 shows the simple definitions used to characterize each value from 1 to 5.

Table 3.1 Assessment Scale

Rating	Description
1	Essentially manual
2	Mostly manual, some automated
3	Equal manual and automation
4	Mostly automatic, some manual
5	Essentially automated

A task is considered essentially manual if it is performed without the benefit of electronic tools or with the benefit of only basic electronic tools such as

a phone or electronic typewriter. An essentially automated task only requires human effort to initiate the process (by pushing a button).

The research team eventually added a "Don't know" category to this scale to allow respondents that do not have sufficient knowledge of an activity to move on without feeling obligated to guess at an assessment.

As discussed later, this 5-point scale was ultimately simplified to the 3-point scale found on version 2.0 and higher surveys.

3.5 Analysis of Respondent, Sample, and Representativeness Issues

Another important element of the survey is a series of questions that characterize the respondent and the project being assessed. The respondent and project need to be characterized not only to help ensure the sample is random and representative of the whole industry, but also to facilitate analysis of the metric by industry sector, size, company type, etc. Table 3.2 contains a list of the characteristics of interest.

First there must be an adequate number of project data points to provide a statistically valid sample. Then, within the sample, the percentage of projects with a given characteristic must be representative of the population. For instance, if 30% of projects done industry-wide are industrial facilities, roughly 30% of the projects assessed in the sample should also be industrial projects.

Table 3.2 Company and Project Characteristics

Characteristic	Category
Technological Sophistication	• Typical • Advanced
Industry Sector	• Industrial • Infrastructure • Buildings
Industry Sub-Sector	• Too numerous to mention here. See "Project Types" on the survey form (Appendix A)
Project Nature	• "Green Field" • Renovation • Expansion
Project Size	• <$5 Million • $5-20 Million • $20-50 Million • $50-100 Million • >$100 Million
Project Location	• State or Country
Project Completion Date	• Month and Year
Respondent's Company Type	• Public Owner • Private Owner • Design Consultant • Prime Contractor • Design-Build Firm • Craft Subcontractor • Supplier
Company Size	• Annual Capital Budget (Owners) • Annual Sales Volume (Contractors)

3.6 FORMULATION OF THE PROJECT PERFORMANCE ASSESSMENT

Measurement of the construction industry's use of automation and integration technologies is important and interesting in an academic sense. However, an assessment of a project's ultimate success and analysis of how that success is related to the use of specific technologies offers the greatest incentive for individual companies to participate in the study since such technology decisions can impact their financial performance.

The project performance assessments used as part of the survey are based on previous work conducted at the University of Texas at Austin (McLeod 1998). They include assessments of cost performance (both total installed cost and operating costs), schedule performance, and safety. These assessments are considered the most fundamental measures of a project's ultimate success and are standard throughout the industry.

Another, rather unique, performance assessment that was added to the survey concerns stakeholder success. It was added as a check to assess the validity of the other performance measures. The assessment asks whether all project stakeholders shared in project success. If they did not, there is an implication that some stakeholders might have achieved success at the expense of others.

3.7 DRAFTING THE SURVEY FRONT-END

The task list and the evaluation scale were the major elements of the survey, but the addition of "front-end" made the survey complete. It included:

- Instructions to the respondent
- Company classification questions
- Project characterization questions
- Project performance assessment

The instructions are intended to clarify the study objectives and to offer respondents some incentive for participating in the study by showing them how the study can help them link technology implementation and project success.

Another important feature of the instructions is the criteria for selecting a project. Respondents are encouraged to choose a project that has recently been completed and that represents either an average or outstanding use of automation and integration technology.

The contact questions serve two purposes. Primarily, they are intended to give researchers a means of re-contacting the respondent if further information is needed. Questions about the person's experience and position on the project team also offer some insight into what sort of qualifications and perspectives the subject has as a basis for his or her assessments.

The company classifications included in the front end allow for in-depth data analysis and are useful in determining the representativeness of a sample.

Project type, location and project I.D. questions are important elements of the survey front end. Type and location data help in insuring the sample is representative of the entire construction industry or one of its sub-sectors. The project identifier is the only means researchers have to identify a project if other project participants need to be contacted for their inputs.

3.8 Preparing the Survey Package (Version 1.0)

Once all the elements of the survey had been developed – the task and integration point listings, the evaluation scale, the project success measures, and the front-end – all that remained was to organize these elements into a coherent package.

The task listing was organized by project phase. Then page breaks were inserted in a way that allowed the survey to be modular or segmented to correspond to each respondent's background and perspective. With the list broken up in this way, the survey length can be customized so a respondent is not overwhelmed by a multitude of questions that do not pertain to his or her role in the project. The same modularization process was carried out on the list of integration links and it was added to the package immediately following the list of tasks. Finally the front-end was put on top and the package was ready to be sent. The completed package spanned eight pages and a fax cover sheet was added to make nine in all.

3.9 Pilot Data Collection and Feedback

The objective of pilot data gathering was to get a small number of companies to review and comment on the survey.

Finding interested industry respondents that spanned the entire spectrum of company and project types proved to be a major hurdle, but the research team was able to discover some creative solutions to this problem. Discussion of these solutions is included here in order to assist future researchers who will, undoubtedly, face similar challenges. Following discussion of the search for

contacts, an examination of the feedback received from those contacts is presented.

Since the Internet has become the latest and greatest tool for companies seeking to build an information infrastructure, it seemed logical for a research team studying information technology to use this tool to conduct its business. So the team began using the Internet to find contacts.

As the Internet has expanded in recent years, several web sites have sprung up to help investors research the financial condition of whole sectors of the economy as well as individual companies. These same web sites provide a great resource for researchers who seek similar information even if the motivations for the search are slightly different.

Hoovers On-line, at www.hoovers.com, was actually the most beneficial Internet-based source of contacts used by the research team. The company profiles on *Hoovers* contain a wealth of information on just a single page and they are free. The most beneficial aspect of these profiles is the single paragraph description of the work performed by the company. It gives a brief history of the company, its major markets, and even the names of its top three competitors. The competitor name listing leverages the search from just one company and one possibility into several. Each competitor name is hyperlinked to the corresponding company profile, which contains another narrative and three more competitor names. The one drawback to this approach is that it finds only the largest, most successful companies, which means the sample is not representative of the whole industry.

Two popular financial magazines – *Forbes* and *Fortune* – have also published web sites that offer lists of companies by industry. These lists give researchers a starting point to begin learning about companies. Once a company name is chosen, there is a wide array of information available about that company. The financial records of a company provide a clue to the company's size, and a corporate office phone number offers the first step toward making contact with a person. Some companies even have corporate web pages that present more detailed information, often including the name of a division chief in charge of construction management. These two web sites can be used to get contacts in commercial owner companies and some of the larger construction firms. However, government owners and small construction organizations remain elusive.

Engineering News Record magazine maintains a web site with an extensive database of construction-related companies. The database includs all types of construction companies from architect-engineers, to general and sub-contractors. One can search the database by company type, project type, location, or any combination of the three.

The Federal Facilities Council (FFC) web site provids the last group of contacts necessary to represent the industry: government owners. These government agencies typically handle most of the infrastructure projects, so they are important to rounding out a sample. The FFC web site and the U.S. Department of Transportation (DOT) web site together provide contact information for almost all agencies involved in construction in the U.S.

Once an interested contact person was found it was time to send a survey. During the pilot data gathering phase only one version of the survey was produced and the sole transmission method was via facsimile. Respondents either returned the completed survey via mail or facsimile. Some comments were received on the returned surveys, but the majority of the feedback came over the phone, or face-to-face during subsequent follow-up interviews.

3.10 FEEDBACK FROM PILOT DATA GATHERING

The Version 1.0 survey was sent to 36 companies on the process of gathering data. Many of those who received the Version 1.0 survey and understood the study's implications for the future of the industry were eager to help make it better.

Some of the feedback came in written form when the survey was faxed or mailed back. Some feedback was gleaned from follow-up interviews conducted over the telephone. By far, however, the most useful and prolific comments came during face-to-face interviews.

The comments were collected into three broad categories:

- Length problems
- Organization problems
- Clarity problems

The length of the survey seemed to be a concern for everyone who received it. Some were intimidated by the length of the survey the instant they saw it and admitted that they did not have time to complete such a lengthy assessment. Others actually completed the survey, but still said that it was too

long. The problem of physical length was compounded by the effort required to understand each question due to some lack of clarity in phrasing.

Organization was a concern for some people, because they felt they were jumping from one context subject to another and back again as they read through the survey. Part of the cause for this problem lay in the separation of automation tasks and integration links into two different parts of the survey package. Because of this separation, the respondent was forced to traverse mentally through the project life-cycle thinking of discrete tasks, and then again with a focus on integration links. The separation made sense on the drawing board, but practically speaking seemed to be cumbersome and increased the perceived length of the survey.

Some also criticized the sequence within particular phases, focusing on the grouping of similar tasks and the issue of chronological order.

Regarding clarity in the language of the survey, there was agreement that the language or structure of the questions was ambiguous in places, forcing respondents to read and re-read each one before understanding it enough to offer an assessment of it. One example cited for its extreme ambiguity was the title of the integration link listing: "Assessment of the Degree of Automation of Integration Links." Respondents specifically cited many other examples so a general rewording effort was undertaken.

Adding to the ambiguity of the survey was the evaluation scale wording. Many respondents felt the term "Essentially Totally Automatic" could be

misleading, and that the rating of 3 ("equal manual and automatic") was unrealistically precise.

The readability of the survey was also impacted by the use of fax machines to transmit it. Occasionally, parts of the survey were reported by the subject to be unreadable. However, the more common occurrence was that the research team could not read parts of the survey when the subject faxed it back. This problem occurred because the document lost some resolution when it was sent to the subject. Then it lost even more on the return transmittal.

3.11 Modification and Refinement of the Survey (Version 2.0)

The pilot data collection effort yielded a lot of good, honest feedback from the target audience. From this effort it was evident that the survey would need revising before it could be used to gather real data. By the time Version 2.0 of the survey was ready for distribution it was almost unrecognizable to those who had seen Version 1.0.

The most fundamental change made to the survey was made to the evaluation scale. The earlier 1-5 scale had caused problems for the participants of the study because the definitions and level distinctions were rather ambiguous. The 5-point scale also contributed to the perceived length of the survey. So, the scale was reduced to a 3-point scale and each point was given a more detailed definition. The scale was also modified to incorporate both concepts of integration and automation. The phases of data integration discussed earlier were used as a model for this new scale. The result was a scale that moved from essentially manual processes, to "islands of automation," to elimination of low

technology bridges. The last phase, full data integration, was left off the scale for the time being based on the assumption that no one could claim to be there yet. A comment line was added to the end of the evaluation scale to allow anyone who thought his or her process exceeded a level three to describe that process.

A table of definitions, examples, and characterizing words was added in each of the project phases to clarify how each level on the scale pertained to the tasks in that phase. Table 3.2 is an example of the table that was placed at the top of every page of the survey.

Part 1. Front End

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Needs Analysis	Traffic counting machines gather data, which is collected periodically and stored in paper files.	Traffic data is stored in a stand-alone GIS database, which is updated periodically.	GIS database linked to citywide sensor network displays real-time traffic data and trends.

Figure 3.5 Assessment Scale Examples

In addition to the numeric changes, a "Not Applicable" option was added to the scale for those respondents who felt a question did not apply to their particular type of project. Many people commented that the "Don't Know" option was not appropriate in such a case.

The length of the survey was reduced in a couple of ways. First, some of the original phases were combined or eliminated to reduce the overall number of

phases. Then, the "litmus test," discussed previously, was re-applied in a more stringent fashion to reduce the total number of questions dramatically. Table 3.3 shows how the phases from the Version 1.0 survey were changed for Version 2.0.

Table 3.3 Changes to Phase Descriptions

	Version 1.0		**Version 2.0+**
1	Market Research/ Needs Analysis; Project Definition/ Programming	1	Front End
2	Conceptual Design & Feasibility/ Schematic Design		
3	Front-End Engineering/ Design Development	2	Design
4	Detail Design/ Working Drawings		
5	Procurement/ Long-Lead Procurement/ Owner-Furnished Equipment	3	Procurement
6	Construction	4	Construction Management
		5	Construction Execution
7	Start-up/ Commissioning	6	Start-up, Operations & Maintenance
8	Operations & Maintenance		
9	Dismantlement	--	This phase was eliminated

Once some of the phases were combined, additional redundancies became clear and those questions were deleted. After obvious redundancy had been eliminated, the litmus test was used to locate the less important tasks and delete them. The final number of questions on the Version 2.0 survey was 76 – a substantial reduction from version 1.0 with its 93 questions.

The construction phase was split into construction management and construction execution in order to draw a clear distinction between the tasks that involved the processing of information – like tracking work progress – from those that involved direct installation work – like welding. The reason for the distinction was that indirect work occurs <u>within</u> the information infrastructure while direct work involves robotic devices (that need the information infrastructure for support).

To improve clarity of the questions the entire list was re-examined in detail and each was re-worded using common language, adding context, and simplifying sentence construction.

Clarity at the question level was not the only concern expressed by participants in the pilot data gathering effort. The initial impression most often expressed about the survey was that it appeared cramped and busy. So the Version 2.0 survey benefited from larger fonts, more empty space, and fewer lines.

One astute participant, upon gaining an understanding of integration links, questioned the wisdom of separating discrete tasks from integration points. Instead of separation he suggested that the integration points be placed immediately following the tasks they related to. It is believed that this approach improved the reader's understanding of the context of each question.

Some respondents felt constrained by the closed nature of the questions that only allowed for an evaluation or no answer at all. This closed format also made the job of interpreting the data somewhat difficult since a discrete number

can conceal a distinctive characteristic of the technology implementation. So, to open the format a little, a short comment line was added at the end of the evaluation scale for each line item to allow respondents to clarify their particular process. An open-ended question was also added to the end of each phase, asking respondents to describe the most beneficial technology used on the project during that phase.

Many questions that were added to the survey front-end will help categorize the data in the future and provide measures of project performance. Questions relating to the project's size and company's size were added as categorizing questions. The project completion date was required as the basis for trend analysis later. Several project outcome measures, like cost, schedule, and safety were also added. These project outcome measures will presumably allow future analysis to correlate technology usage with project success and thereby offer participants some way to predict the return on their technology investment.

During the transition between Version 1.0 and Version 2.0, there were many drafts, so it was important to have a systematic way of organizing them. The scheme that was adopted was fairly simple. Whenever a cosmetic change was made that did not affect the usability of the data collected by the previous version, only a decimal change was made. If the change rendered data from the previous version unusable, the version was changed by a whole number. For example, adding a question or deleting a question only warranted a change from, say, 1.0 to 1.1. However, if the wording of the question was modified or the rating scale was altered, the version number would change from 1.0 to 2.0.

The problem of reducing resolution through multiple faxes was addressed in two ways. An electronic version of the survey that could be sent via electronic mail (e-mail) was created, and the research team began sending faxes directly from a computer rather than printing the form and sending it through a fax machine.

The electronic version of the survey was constructed as a data processing form using Microsoft Word. It contained input fields that allowed the respondent to type responses. Once all the fields were filled in, the form could be saved and sent back via e-mail without the loss of resolution common in the faxing process.

One very important issue that arose with the use of an electronic form was compatibility. In order to make the format compatible with the majority of the word processing software on the market – Microsoft, WordPerfect, and Macintosh – the Rich Text Format (RTF) was chosen. This format allowed for use of input fields and graphics, while still maintaining compatibility.

File size was also important to consider when sending an e-mail attachment. The file size had to be kept to a minimum to ensure upload and download times were reasonable. Many recipients had only a modem connection or a slow network connection and they did not want to wait all day for the file to download.

Besides download time, the restrictions imposed by certain e-mail services made minimizing file size important. Some restrict the space available in a person's mailbox and others place a maximum file size limit on incoming or outgoing mail messages.

The file size was minimized by sacrificing aesthetics for content. Even the simplest straight line was scrutinized since even simple graphics ballooned the file size dramatically.

Most of the participants in the survey either did not have e-mail or preferred a faxed copy, so the electronic form was not an option in most cases. Therefore, to solve the problem of diminishing fax quality, the surveys were sent directly from a computer using off-the-shelf faxing software and a fax/data modem. This procedure improved quality by eliminating one document-scanning step from the typical faxing process. The receiving fax machine became essentially a remote laser printer.

3.12 Data Collection

Data is being collected a number of different ways, and each has advantages and disadvantages. The most efficient method is through phone calls and faxes. Although this method is not the most fruitful, since the return rate was quite low. It is not surprising that a more effective method of data collection involves personal interviews. This method is more labor intensive and more costly, but the data acquired is much more illuminating. The issues of data collection and analysis will be dealt with in more depth by others (Kumashiro, etc.).

Chapter 4 The Survey Form and Commentary

This chapter presents commentary on selected parts of the data gathering tool created through the process described in the previous chapter. Parts of the latest version of the survey are displayed with notes describing elements of interest. The notes have been compiled from comments made by respondents during interviews conducted as part of pilot data gathering and are intended to guide future researchers as they conduct their own interviews. Note that only the major elements of interest are presented here. A copy of the entire survey can be found in Appendix E.

1 Many respondents have not understood that they are being asked to evaluate the technology use of a particular project, so they try to complete the assessment for the company as a whole. This point is crucial because an assessment at the company level does not allow comparison of technology use with project performance. Consequently, respondents are reminded that their assessments must be of a *particular* project. Secondly, the respondents must feel secure that the data they provide will not be published in a manner that reveals them as the source. Any published material must separate the respondent company from the actual responses.

2 Respondents need to understand that one person is not expected to have the requisite knowledge to fill out the entire survey single-handedly. If a respondent feels compelled to answer all the questions, two results have been observed: either the respondent feels the time commitment required to complete

Directions

Purpose

The purpose of this survey is to assess the level of technology used on individual construction projects as well as to provide an understanding of the project's cost schedule and safety performance.

Directions

- Please complete the survey as directed bearing in mind that the survey should be answered in the context of a particular project. **All data will be held in strict confidence.** 1
- Feel free to answer only those questions for which you have a sufficient level of experience or knowledge. *It is not necessary to answer all questions* 2
- If you wish to complete a survey for more than one project, please contact the undersigned, and additional copies will be provided to you (or you may make copies of the blank survey in your possession).
- Please contact James T. O'Connor at (512) 471-4645 with any comments or questions.
- Survey results should be sent to the following address:

James T. O'Connor
Department of Civil Engineering
ECJ 5.200 M/C C1700
University of Texas
Austin, TX 78712

Fax: (512) 471-3191
e-mail: jtoconnor@mail.utexas.edu

Figure 4.1 Survey – Directions

3 **Contact Information**

Contact Name:

Phone Number: (   ) -

Fax Number: (   ) -

E-mail Address:

Contact's Perspective: *which of the categories below best describes your perspective of the project?*

- ☐ Business Unit (project initiator, investor, senior management)
- ☐ Project Team (responsible for delivering an operational facility)
- ☐ Operations (responsible for operation of the completed facility)

Experience: *how many years of experience have you had in this position?* ☐ <5 ☐ 5-10 ☐ 10-20 ☐ >20

4 **Company Information**

Company Name:

Company Type:

- ☐ Public Owner
- ☐ Private Owner
- ☐ Design Consultant or A/E
- ☐ Prime Contractor or GC
- ☐ Design-Build or EPC
- ☐ Supplier or Fabricator
- ☐ Subcontractor
- Other (please describe): ____________

Company Size:

Owners ($ Annual Capital Budget): ____________

A/E's & Contractors ($ Annual Sales Volume): ____________

5 **Project Information**

Project Name:

Project Location:

Domestic ____________ State (U.S.)

International ____________ Country

Project I.D. *You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and CII/Sloan personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries*

Project Completion Date: ________ ☐ actual ☐ projected

Total Installed Cost: ☐ <$5 Million ☐ $5-20 Million ☐ $20-50 Million ☐ $50-100 Million ☐ >$100 Million

Project Nature: ☐ "Green Field" ☐ Renovation ☐ Expansion

Integration & Automation on Construction Projects i Version 2.2

Figure 4.2 Survey – Company Information

5

Project Information (continued)

Project Type: *of the project types listed below, which best describes your project?*

Industrial
- ☐ Foods
- ☐ Pharmaceuticals Mfg.
- ☐ Consumer Products Mfg.
- ☐ Automotive
- ☐ Microelectronics Mfg.
- ☐ Pulp and Paper
- ☐ Power Generation
- ☐ Petroleum Refining
- ☐ Chemical Mfg.
- ☐ Oil & Gas Production
- ☐ Environmental / Remediation
- ☐ Metals Refining/Processing

Infrastructure
- ☐ Water/Wastewater
- ☐ Electrical Distribution / Communications
- ☐ Tunneling
- ☐ Highway
- ☐ Airport
- ☐ Rail
- ☐ Flood Control
- ☐ Navigation
- ☐ Marine Facilities
- ☐ Mining
- ☐ Solid Waste Management

Buildings
- ☐ Single-unit Residential
- ☐ Multi-unit Residential (low-rise)
- ☐ Multi- unit Residential (mid-rise and high-rise)
- ☐ Hotel / Motel
- ☐ Low-rise Office
- ☐ Mid-rise Office
- ☐ High-rise Office
- ☐ Retail
- ☐ Parking Garage
- ☐ Warehouse
- ☐ Educational
- ☐ Hospital / Clinic
- ☐ Laboratory
- ☐ Correctional
- ☐ Entertainment

6

er: *(please specify)* ______________________

Cost Performance:

The total installed cost of the project was...
- ☐ Significantly under authorized Budget
- ☐ Essentially the same as Authorized Budget
- ☐ Significantly over Authorized Budget

After 4-6 months of operations, the operating cost of the facility was . . .
- ☐ A problem
- ☐ Not a problem
- ☐ Don't know

Schedule Performance:

The actual project completion date was...
- ☐ Significantly earlier than planned
- ☐ Essentially the same as the planned
- ☐ Significantly later than planned

The actual operations start date was...
- ☐ Significantly earlier than planned at authorization
- ☐ Essentially at the planned start date
- ☐ Significantly later than planned at authorization

Safety: *were there any OSHA reportable injuries during the project?*
- ☐ Yes
- ☐ No
- ☐ Don't know

Stakeholder Success: *e.g. owner, A/E, contractor, etc.* 7
- ☐ All project stakeholders shared in project success
- ☐ Nearly all project stakeholders shared in project success
- ☐ Only some project stakeholders shared in project success

Can a significant portion of the project outcome be credited to (or blamed on) the use of technology? ☐ Yes ☐ No 8

How does the degree of technology use on this project compare with other projects your company has participated in? 9

☐ Typical ☐ Advanced

Integration & Automation on Construction Projects ii Version 2.2

Figure 4.3 Survey – Project Information

Part 1. Front End

10

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Needs Analysis	Traffic counting machines gather data, which is collected periodically and stored in paper files.	Traffic data is stored in a stand-alone GIS database, which is updated periodically.	GIS database linked to citywide sensor network displays real-time traffic data and trends.

11 12 13

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
1.01	Conduct market analysis or need analysis for a new facility	☐	☐	☐	☐	☐	
1.02	Develop, evaluate, and refine the project's scope of work	☐	☐	☐	☐	☐	
1.03	Diagram the manufacturing process -or- the user's processes ("bubble diagram")	☐	☐	☐	☐	☐	
1.04	Estimate a budget from the scope of work	☐	☐	☐	☐	☐	
1.05	Develop a milestone schedule from the scope of work	☐	☐	☐	☐	☐	
1.06	Acquire and store site investigation data for use during design	☐	☐	☐	☐	☐	

1.07 Describe the most beneficial technologies used in *front-end* processes at your company: 14

15

Integration & Automation on Construction Projects 1-1 Version 2.2

Figure 4.4 Survey – Front End Phase Technology Assessment

the survey is too great and consequently decides not to complete it; or the answers that are provided are less accurate since the respondent had insufficient knowledge of the tasks being assessed. The second scenario of a respondent answering outside his or her area of expertise can be very damaging since it is hard to detect whether the answers are accurate or not. Therefore, respondents are encouraged to complete only the parts of the survey with which they feel sufficiently experienced.

3 Contact information serves two important purposes. First, the researcher who receives the survey needs to have enough information to re-establish contact with the respondent in case additional questions must be asked to clarify responses or complete the data set. Furthermore, the questions of project perspective and experience serve to qualify the respondent's assessment. For example, a respondent with a very limited perspective of the project, such as the business unit, and only a few years of experience could not be expected to answer all the questions on the survey.

4 Company information permits comparison of the data based on company type and company size.

5 Project information serves to identify the particular project so that its assessment can be matched to the company and contact information in case a question arises later that must be clarified with the respondent. The completion date not only points out whether the project has been completed or not, but also places the project in time so data can be analyzed for temporal trends. Most importantly, the project data offers a basis for comparison of the assessment and

outcome data. Projects can be compared by size, nature (i.e. "green field", renovation, or addition), installed cost, industry sector, and by project type.

6 Each of these project success measures can be compared to the technology assessment data to see if technology use yields any improvement in project outcome.

7 The measure of stakeholder success is a unique form of project success measure designed to test the validity of the other indicators of project outcome. For example, if the project was a success as measured by cost, schedule, and safety performance, but not all the project's stakeholders shared in that success, there is an implication that some stakeholders may have achieved success at the expense of others.

8 Respondents are asked to reveal any extenuating circumstances that may have contributed to, or detracted from, the success of the project independent of the use of technology. If there were indeed extenuating circumstances affecting the project, an argument can be made to exclude the data point from analysis.

9 Knowing whether the chosen project is typical or more sophisticated than most projects in its use of technology gives a rough estimate of where the cutting edge lies in the industry versus the average level of technology implementation.

10 A table is placed at the beginning of every section of the assessment to give the respondent a clear idea of what is meant by each level of the

assessment scale. The characterization words and examples are different for each phase since each phase involves different sorts of tasks.

11 The question identification number is important for keeping track of data as it is entered into a database for analysis.

12 The degree of technology use assessment gives the respondent a scale that corresponds to the examples given in item 10. The "Don't Know" and "N/A" options were placed at opposite ends of the assessment scale to prevent confusion between the two as a respondent moves down the page. Many respondents expressed concern that processes did not meet level 3 criteria in many cases. The interviewer must reassure the respondent that it is both natural and expected that most processes will not achieve level 3 because some room for growth and improvement has been built into the survey.

13 A comment line was added to the end of the assessment line to give respondents some flexibility as they complete the survey. Some respondents felt it was important to have the ability to make clarifying comments if their answer did not fit neatly into the assessment scale. Previous versions of the survey limited the usefulness of this comment line by asking respondents to describe their process if they thought it was more sophisticated than a level three. With such a restrictive question, the comment line was almost never used.

14 An open-ended question was added to the end of each phase to invite respondents to describe their technological accomplishments. This question also allows respondents to share processes that they feel are benchmarks that could benefit the industry as a whole.

15 The footer at the bottom of the page includes a page number and version number to eliminate confusion when discussing the survey over the phone. During the pilot data gathering process, there were many confusing circumstances when the respondent and the researcher each had a different version of the survey or had the same versions but were on different pages. Simply placing this information at the bottom of every page will prevent these frustrating events from happening again.

Chapter 5 Conclusions and Recommendations

Construction has become a business of tight profit margins and rapidly changing environments. And in such a dynamic realm, integrative technologies offer great potential for competitive advantage to those who are the first to harness their power. Unfortunately, early implementation often leads to frustration and disappointment, sometimes because there is no quantitative data on which to base implementation decisions.

The Sloan Program at the University of Texas at Austin is in search of that quantitative data with which to guide future project-level technology implementation and subsequently improve project outcomes. This report represents a first step toward achieving that goal: the development of a survey that measures both the degree of technology use throughout project life-cycles and the implications of such technology on project outcomes.

5.1 CONCLUSIONS

- The construction industry sees integration throughout the project life-cycle as a worthwhile goal.
- There is very little quantitative data on the current use of specific technologies within capital facility delivery.
- There is very little quantitative data correlating technology use with project performance.
- A structured, consistent interview process is necessary to allow comparison of assessment data.
- Limiting survey length, and even perceived length, is important for a survey to be successful.

- It is difficult to develop a list of project tasks that apply to every type of project and company in the construction industry.

- Clear wording is crucial to the effectiveness of any survey. However, clear phrasing of automation task and integration link descriptions is difficult to achieve without implying a current technology paradigm, which limits the usefulness of the survey over time.

- Using plenty of blank space on each page helps prevent the form from looking busy and crowded.

- A version numbering system should be developed early and be applied in a disciplined manner. Then, time must be taken to document the changes made between versions and the reasons for those changes.

- An electronic survey form can eliminate the loss of resolution common in the faxing process while still allowing an almost instant transmission.

5.2 RECOMMENDATIONS

- The research team should continue using the Internet to find contacts and companies. And they should devise new strategies that leverage the power of the Internet to simplify the data-gathering process.

- Researchers should be mindful that face-to-face interviews achieve both higher response rates and better data than those conducted through fax or e-mail despite their higher cost.

- Any published material must protect the confidentiality of the respondent by separating assessment data from respondent classification data.

- Respondents must understand that no one person has the requisite knowledge to fill out the entire survey single-handedly.

- The research team should continue seeking ways to simplify the survey and to reduce the time required of respondents to complete it.

Appendix A – Survey Version 1.0

Survey on Task Automation and Integration

Version 1, Revision 5/19/98

Background and Motive

This research is being conducted by the Sloan Program at the University of Texas at Austin. In the construction industry advanced technologies are being used increasingly to improve project performance. Such technologies are applied in two ways:

- Task Automation—eliminating or reducing the need for human input or interaction
- Task-to-Task Integration—facilitating the transfer of information across otherwise restrictive boundaries, both physical and non-physical.

The construction industry can benefit from benchmarking work processes and better understanding the impacts of advanced technology.

Survey Objectives & Guidelines

Please use the attached survey to assess the degree of automation associated with your work processes on a particular project. The survey is presented in three parts:

Part I—Project and Respondent Information

Part II—Assessment of Degree Task Automation

Part III—Assessment of Degree of Automation of Integration Links

Each survey response should pertain to a single project that you identify (if you wish to provide a response for more than one project, please do so on another copy of the questionnaire).

The project you select should fall into one of two categories:

- Typical level of automation—the project used automation practices and procedures that are commonly used throughout the company on other projects.
- Advanced level of automation—the project used automation practices and procedures that were relatively sophisticated compared with other projects.

Please do not assess a project considered less advanced than average for your company.

You may find it easier to complete the survey if:

- The selected project has been recently completed or is near completion
- Associated project personnel are still available and have a clear memory of the project's characteristics

Returning the Survey

Survey results should be mailed or faxed to:

James T. O'Connor
Dept. of Civil Engineering
ECJ 5.200 M/C C1700
University of Texas
Austin, TX 78712

Fax: (512) 471-3191
Office: (512) 471-4645

PART I
Project / Respondent Information

Project / Company Information

Your Company: ____
Your Project I.D. # __________ (You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and Sloan Program personnel identify the survey correctly if clarification of data is needed and to prevent duplicate project entries.)
Relative to all projects in which your company is involved, this project was _____typical _____advanced in its use of automation and integration technologies.
Project Location: Domestic ____________________, USA International
____

State

Country
Type of Projects (check only one. If the project does not appear in the list, please describe in the space next to "Other."):

Industrial	Infrastructure	Buildings
____ Foods	____ Water/Wastewater	____ Single-unit Residential
____ Pharmaceuticals Mfg.	____ Electrical Distribution / Communications	____ Multi-unit Residential
____ Consumer Products Mfg.	____ Tunneling	____ Mid-rise Residential
____ Automotive Mfg.	____ Highway	____ Hotel / Motel
____ Microelectronics Mfg.	____ Airport	____ Low-rise Office
____ Pulp and Paper	____ Rail	____ Mid-rise Office
____ Power Generation	____ Flood Control	____ High-rise Office
____ Petroleum Refining	____ Navigation	____ Retail
____ Chemical Mfg.	____ Marine Facilities	____ Parking Garage
____ Oil & Gas Production	____ Mining	____ Warehouse
____ Environmental / Remediation		____ School
____ Metals Refining/Processing		____ Hospital
		____ Laboratory
		____ Prison

Other (please describe): ____

____

This project was (check only one): "Green Field"________ Modernization _________ Addition _______

- Green Field – a new facility from the foundations up. A project requiring complete demolition of an existing facility before new construction begins is also classified as grass roots.
- Modernization – a facility for which a substantial amount of existing equipment, structure, or other components is replaced or modified, and which may also expand capacity.
- Addition – a new addition that is physically connected to an existing facility (additions are often intended to expand capacity)

Respondent Information

Contact Person (name of person filling out this form): ______________________________
Contact Position: ______________________________ 9. Years of Experience in Industry: ______
- Contact Phone No. ____________________ 11. Contact Fax No. ______________________

PART II

Assessment of Degree of Task Automation

Please assess the degree of automation for each TASK by placing a check mark in the box that best describes the degree of automation for the TASK in question:

1 – Fully manual
2 – Mostly manual, some automation
3 – Equal manual, automation
4 – Mostly automated, some manual
5 – Fully automated

Please answer only those questions for which you have a sufficient level of experience or knowledge. Do not feel obligated to answer questions outside your area of expertise

Automation Task ID	Automation Task Description	Degree of Automation					
		1	2	3	4	5	Don't Know
Market Research / Needs Analysis; Project Definition / Programming							
1.1	Market demand/needs/price tracking & projection						
1.2	Itemize requirements/develop detailed scopes of work						
1.3	Select/analyze site/existing facility						
1.4	Develop Project Execution Plan						
1.5	Plan manufacturing process/User process (bubble diagram)						
1.6	Identify project objectives						
Conceptual Development & Feasibility / Schematic Design							
2.1	Develop conceptual cost estimate & economic analysis						
2.2	Develop process flow diagram/Facility circulation analysis						
2.3	Plan mechanical systems						
2.4	Plan instrumentation & controls systems						
2.5	Develop conceptual project schedule						
2.6	Develop P&ID/Identify major equipment						
2.7	Develop conceptual plot plan & facility layout						
2.8	Assess available ROW/Existing utilities						
2.9	Plan foundation & structural systems						
2.10	Conduct conceptual technical feasibility analysis						
Front-End Engineering / Design Development							
3.1	Develop detailed facility layout, floor plans, & elevations						
3.2	Develop master detailed project schedule						
3.3	Develop P&IDs (approved for detailed design)						
3.4	Develop guide specs/design guidelines						
3.5	Optimize design for operations/energy usage						
3.6	Develop detailed cost estimate & final economic analysis						
3.7	Select major equipment						

Continued

PART II (Continued)

Automation Task ID	Automation Task Description	Degree of Automation					
		1	2	3	4	5	Don't Know
Detailed Design / Working Drawings							
4.1	Develop detailed material quantity take-off						
4.2	Analyze fluid flow loads & stresses						
4.3	Size piping/plumbing members						
4.4	Analyze structural loads and stresses						
4.5	Size structural members						
4.6	Analyze energy loads						
4.7	Track detailed design progress						
4.8	Develop/customize construction specifications						
4.9	Size & select instrumentation						
4.10	Configure architectural connections/construction details						
4.11	conduct owner design reviews						
4.12	Conduct constructability reviews						
4.13	Conduct code compliance checks						
4.14	Detect interferences between design components of different disciplines						
4.15	Determine design phase % complete based on data from different disciplines						
Procurement / Long-Lead Procurement / Owner-Furnished Equipment							
5.1	Control/monitor equipment for manufacture/fabrication						
5.2	Plan logistics/transport of major components						
5.3	Tabulate & evaluate bids/proposals						
5.4	Assemble bid packages: both technical & commercial						
5.5	Determine procurement lead times						
5.6	Conduct pre-ship testing of equip/engineered components						
Construction							
6.1	Update/verify as-built drawings (configuration model)						
6.2	Measure field work progress/percent complete						
6.3	Manage/track field materials						
6.4	Align underground pipeline/piping						
6.5	Develop detailed construction schedule						
6.6	Prepare structural shop drawings						
6.7	Weld on-site piping						
6.8	Track field personnel and associated work activity						
6.9	Vertical alignment/surveying						
6.10	Select crane for heavy lifts						
6.11	Fabricate roof trusses/joists						
6.12	Earthwork grading						
6.13	Connect structural steel members						
6.14	Transport field materials						
6.15	Maintain daily job diary						
6.16	Fabricate sheet metal HVAC ducts						
6.17	Pull electrical/communication wire						
6.18	Test soil density						
6.19	Conduct field concrete strength tests						
6.20	Apply fireproofing to structural steel members						
6.21	Insulate piping						
6.22	Provide elevated worker access						
6.23	Paint wall/structure						
6.24	Assess subsurface conditions						
6.25	Finish floor slab/paving concrete						
6.26	Manipulate & align sheet rock						
6.27	Documenting and updating field work-hours spent						
6.28	Assess/record position data associated with site/terrain						

Notes:

Continued

Degree of Task Automation

1 - Fully manual
2 - Mostly manual, some automation
3 - Equal manual, automation
4 - Mostly automated, some manual
5 - Fully automated

PART II (Continued)

Automation Task ID	Automation Task Description	Degree of Automation					
		1	2	3	4	5	Don't Know
Startup / Commissioning							
7.1	Develop punch list						
7.2	Test facility/plant control system						
7.3	Analyze startup risks						
7.4	Train facility operators						
7.5	Test first product						
Operations & Maintenance							
8.1	Monitor & assess equipment operations						
8.2	Document/track equipment maintenance history						
8.3	Scope & schedule maintenance activities						
8.4	Update/maintain model/dwgs. of facility physical config						
8.5	Monitor/track facility energy usage						
8.6	Monitor/control facility security & access						
8.7	Control facility thermal/lighting systems						
8.8	Monitor/ytrack facility non-energy utilities usage						
8.9	Monitor facility structural loads & performance						
8.10	Monitor water quality						
8.11	Monitor air quality						
8.12	Periodically inspect facility condition						
Dismantlement							
9.1	Manage information on contaminants/hazardous waste						
9.2	Identify materials/components						
9.3	Manage information on materials-to-be-salvaged						
9.4	Control structural demolition/blasting						

Notes:

Degree of Task Automation

1 - Fully manual
2 - Mostly manual, some automation
3 - Equal manual, automation
4 - Mostly automated, some manual
5 - Fully automated

PART III
Assessment of Degree of Automation of Integration Links

Please assess the degree of automation for each INTEGRATION LINK by placing a check mark in the box that best describes the approach on this project:

1 – Fully manual
2 – Mostly manual, some automation
3 – Equal manual, automation
4 – Mostly automated, some manual
5 – Fully automated

Please answer only those questions for which you have a sufficient level of experience or knowledge.
Do not feel obligated to answer questions outside your area of expertise

Integration Link ID	Integration Link Description	Degree of Automation					
		1	2	3	4	5	Don't Know
Market Research / Needs Analysis; Project Definition / Programming							
1.1	Nature of link between Scope Definition Statements and Needs Analysis						
1.2	*Nature of link to information pertaining to existing site/facility/utilities*						
Conceptual Development & Feasibility / Schematic Design							
2.1	Nature of link between facility/process engineering analyses models and existing facility configuration models/as-builts						
2.2	Nature of link between cost estimate and scope/conceptual design information						
2.3	Nature of link between project schedule/sequences and scope/conceptual design information						
Front-End Engineering / Design Development							
3.1	Nature of link between DETAILED design/configuration models and CONCEPTUAL design/configuration models						
3.2	Nature of link between listings of needed equipment, instrumentation, etc. and conceptual design model						
3.3	Nature of link between equipment/component selection and associated cost data						
3.4	Nature of link between list of preferred suppliers and needed equipment (equipment listing)						
3.5	Nature of link between design/configuration models and site data/as-built models						
3.6	*Nature of link between major construction method selection and associated cost data*						
3.7	Nature of link between equipment selection and company equipment standards						

Continued

PART III (Continued)

Integration Link ID	Integration Link Description	Degree of Automation					
		1	2	3	4	5	Don't Know
Detailed Design / Working Drawings							
4.1	Nature of the communication link between design consultants and suppliers/manufacturers for sharing design configuration data & specs						
4.2	Engineer's approach to acquiring design configuration data for the purpose of configuring and sizing structural members						
4.3	Engineer's approach to acquiring design configuration data for the purpose of configuring and sizing piping systems						
4.4	Engineer's approach to acquiring design configuration data for the purpose of determining structural loads						
4.5	Engineer's approach to acquiring design configuration data for the purpose of conducting an energy load analysis						
4.6	Nature of the link between developing the detailed cost estimate and supplier cost data						
Procurement / Long-Lead Procurement / Owner-Furnished Equipment							
5.1	Approach to acquiring a listing of major equipment that is included in the project						
5.2	Approach to acquiring/receiving supplier price quotes						
5.3	Nature of the link between fabricators and design/configuration information (drawings etc.)						
5.4	Approach to acquiring status information on major equipment under fabrication						
5.5	Approach to transmitting invoices from contractors to owner or architect/engineer						
5.6	Approach to acquiring results from pre-shipment tests and inspections from the fabrication shops						
5.7	Nature of the communication link between suppliers and field material management/field warehouse inventory management						
5.8	Approach to transmitting the requests for price/requests for proposal to prospective suppliers						
5.9	Nature of the communication link between suppliers and owner/contractor purchasing personnel						
Construction							
6.1	Nature of the link between updated short-interval work schedule and information on availability of materials & equipment						
6.2	Nature of link between updated short-interval work schedule and information on recent actual crew site progress						
6.3	Approach toward transmitting shop drawings between fabricators/subcontractors and design consultants						
6.4	Nature of the communication link between workface site crews and material/equipment warehouse						
6.5	Nature of the link between impact to contractor's schedule and design change information						
6.6	Nature of the link between contractor's cost impact and design change information						
6.7	Nature of the link between site work crews and design configuration data/drawings						
6.8	Nature of communication link between site work crews and change order approval status information						
6.9	Nature of link between the detailed construction schedule and updated detailed design/configuration data						
6.10	Nature of communication link between site work crews and RFI status & response information						

Notes:

Continued

Degree of Integration Link Automation

1 - Fully manual
2 - Mostly manual, some automation
3 - Equal manual, automation
4 - Mostly automated, some manual
5 - Fully automated

PART III (Continued)

Integration Link ID	Integration Link Description	Degree of Automation					
		1	2	3	4	5	Don't Know
Startup / Commissioning							
7.1	Nature of link between startup system degree of completion and construction discipline/area progress for purposes of planning turnover						
7.2	Nature of link between facility operations model (for systems monitoring) and facility design/configuration data						
7.3	Nature of link between maintenance training manuals and facility design/configuration data						
7.4	Nature of link between operator training manuals and equipment supplier information						
Operations & Maintenance							
8.1	Nature of link between equipment maintenance planning and historical maintenance information						
8.2	Nature of link between updated as-built configuration models and maintenance modifications						
8.3	Nature of link between equipment/parts procurement and maintenance activity data						
8.4	Nature of link between equipment maintenance planning and facility design/configuration data						
8.5	Nature of communication link for gathering/documenting requests for facility modifications						
Dismantlement							

Notes:

Degree of Integration Link Automation

1 - Fully manual
2 - Mostly manual, some automation
3 - Equal manual, automation
4 - Mostly automated, some manual
5 - Fully automated

Appendix B – Survey Version 2.0

Fax

To:		**From:**	University of Texas at Austin Dept of Civil Engineering
Fax:	( ) -	**Fax:**	(512) 471-3191
Phone:	( ) -	**Phone:**	(512) 471-
Re:	Automation & Integration Survey	**Pages:**	6

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☑ **Please Reply**

• **Comments:**

I am a graduate student in Civil Engineering at the University of Texas. I am studying how the construction industry uses technology to improve project performance by automating tasks and by managing the flow of information throughout the lifecycle of a project. Ultimately the data you provide will assist you and your organization by showing you how to extract the greatest return on your investment in new technology.

Please find attached, Parts 1-6 of our survey.

A couple of comments on the survey:

- When answering survey questions, consider a completed project for which you have knowledge or experience.
- Our ultimate goal is to track the use of technologies in relation to project performance. Thus, we may send you a follow-up survey to answer questions related specifically to project performance.

You questions are welcome. Please respond by <u>Wednesday 9/2</u> or at your earliest convenience. Thank you in advance for your assistance

Graduate Research Assistant
University of Texas at Austin

E-mail:

Respondent and Project Information

Company Name:	
Company Type:	☐ Public Owner ☐ Private Owner ☐ Design Consultant or A/E ☐ Prime Contractor or GC ☐ Design-Build or EPC ☐ Supplier or Fabricator ☐ Subcontractor Other (please describe):

Name:	**Perspective:** *which of the categories below best describes your perspective of the project?*
Phone Number: ( ) - **FAX Number:** -	☐ Business Unit [project initiator, investor, senior management] ☐ Project Team [responsible for delivering an operational facility] ☐ Operations [responsible for operation of the completed facility]
E-mail Address:	**Experience:** *how many years of experience have you had in this position?* ☐ <5 ☐ 5-10 ☐ 10-20 ☐ >20

Project Type: of *the project types listed below, which best describes your project?*

Industrial	Infrastructure	Buildings
☐ Foods	☐ Water/Wastewater	☐ Single-unit Residential
☐ Pharmaceuticals Mfg.	☐ Electrical Distribution / Communications	☐ Multi-unit Residential
☐ Consumer Products Mfg.	☐ Tunneling	☐ Mid-rise Residential
☐ Automotive	☐ Highway	☐ Hotel / Motel
☐ Microelectronics Mfg.	☐ Airport	☐ Low-rise Office
☐ Pulp and Paper	☐ Rail	☐ Mid-rise Office
☐ Power Generation	☐ Flood Control	☐ High-rise Office
☐ Petroleum Refining	☐ Navigation	☐ Retail
☐ Chemical Mfg.	☐ Marine Facilities	☐ Parking Garage
☐ Oil & Gas Production	☐ Mining	☐ Warehouse
☐ Environmental / Remediation	☐ Solid Waste Management	☐ Educational
☐ Metals Refining/Processing		☐ Medical
		☐ Laboratory
		☐ Correctional

Other:

Project Size: ☐ <$5 Million ☐ $5-20 Million ☐ $20-50 Million ☐ $50-100 Million ☐ >$100 Million

Cost Performance: *The total installed cost of the project was...*	**Schedule Performance:** *The actual operations start date was...*
☐ Significantly under Authorized Budget	☐ Significantly earlier than Planned at Authorization
☐ Essentially the same as Authorized Budget	☐ Essentially the same as the Planned start Date
☐ Significantly over Authorized Budget	☐ Significantly later than Planned at Authorization

Part 1.
Front End

	Level 1	Level 2	Level 3
Degree of Technology Use	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
Characterization	Hardcopy → Human to human → "Give me a call" → Proximity is important →	Floppy disk → Human to machine → "Bring me a disk" → Proximity is less important →	Network Machine to machine "The file is on the network" Proximity is irrelevant
<u>Example:</u> Needs Analysis	• Traffic counting machines gather data, which is collected periodically and stored in paper files.	• Traffic data is stored in a stand-alone GIS database, which is updated periodically.	• GIS database linked to citywide sensor network displays real-time traffic data and trends.

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process
1.01	Conduct market analysis or need analysis for a new facility	☐	☐	☐	☐	☐	
1.02	Develop, evaluate, and refine the project's scope of work	☐	☐	☐	☐	☐	
1.03	Diagram the manufacturing process -or- the user's processes ("bubble diagram")	☐	☐	☐	☐	☐	
1.04	Estimate a budget from the scope of work	☐	☐	☐	☐	☐	
1.05	Develop a milestone schedule from the scope of work	☐	☐	☐	☐	☐	
1.06	Acquire and store site investigation data for use during design	☐	☐	☐	☐	☐	

1.07 Describe the most beneficial technologies used in *front-end* processes at your company:

1.08 Describe the most sophisticated technologies used in *front-end* processes at your company:

Part 2.

Design

Design	Level 1	Level 2	Level 3
Degree of Technology Use	No electronic tools -or-Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
Characterization	Hardcopy → Human to human → "Give me a call" → Proximity is important →	Floppy disk → Human to machine → "Bring me a disk" → Proximity is less important →	Network Machine to machine "The file is on the network" Proximity is irrelevant
Example: Design Structural System	• Designer gets loads from a manual: puts a concept on paper; passes to a draftsman who draws by hand. Details are cut and pasted on drawings.	• Designer gets loads from stand-alone software; puts a concept on CAD and gives the disk to a CAD technician for details	• Designers from all disciplines collaborate on a network with a common CAD model. Details automatically added from database

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
2.01	Designers access supplier information in order to select components	☐	☐	☐	☐	☐	
2.02	Get input from operators and builders regarding construction methods selection, & construction sequencing	☐	☐	☐	☐	☐	
2.03	Analyze alternative construction methods for effects on cost, schedule, etc.	☐	☐	☐	☐	☐	
2.04	Use conceptual design work as a basis for detailed design work	☐	☐	☐	☐	☐	
2.05	Generate facility floor plans	☐	☐	☐	☐	☐	
2.06	Design the fluid transport system (open channel or pipes) and related drawings	☐	☐	☐	☐	☐	
2.07	Design the structural system and related drawings	☐	☐	☐	☐	☐	
2.08	Design the electrical system and related drawings	☐	☐	☐	☐	☐	
2.09	Design the HVAC system and prepare related drawings	☐	☐	☐	☐	☐	
2.10	Document the assumptions used in developing the budget, and pass to the next phase	☐	☐	☐	☐	☐	
2.11	Detect physical interference between systems (i.e. plumbing, electrical, structural, etc.)	☐	☐	☐	☐	☐	
2.12	Prepare project specifications	☐	☐	☐	☐	☐	
2.13	Check the design against owner requirements (e.g. design reviews) and code requirements	☐	☐	☐	☐	☐	
2.14	Track design progress	☐	☐	☐	☐	☐	

2.15 Describe the most beneficial technologies used during *detailed design* at your company:

Part 3.

Procurement	Level 1	Level 2	Level 3
Degree of Technology Use	No electronic tools -or-Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
Characterization	Hardcopy → Human to human → "Give me a call" → Proximity is important →	Floppy disk → Human to machine → "Bring me a disk" → Proximity is less important →	Network Machine to machine "The file is on the network" Proximity is irrelevant
Example: Bid Proposal	Get paper copies of drawings/specs Input the prices in a spreadsheet Hand a hard copy of proposal to owner	Get CD-ROM files of CAD model Compile bid with special software Give owner a disk copy of proposal	Download CAD files from network Get bids from subs electronically Transmit file via network to owner

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
3.01	Determine the lead time required to order equipment and materials	☐	☐	☐	☐	☐	
3.02	Conduct a quantity survey of drawings	☐	☐	☐	☐	☐	
3.03	Link quantity survey data to the cost estimating process	☐	☐	☐	☐	☐	
3.04	Link supplier cost quotes to the cost estimating process	☐	☐	☐	☐	☐	
3.05	Refine the preliminary budget estimate	☐	☐	☐	☐	☐	
3.06	Develop the milestone schedule	☐	☐	☐	☐	☐	
3.07	Develop and transmit requests for proposal to suppliers and subs	☐	☐	☐	☐	☐	
3.08	Prepare & submit shop drawings	☐	☐	☐	☐	☐	
3.09	Acquire & review shop drawings; send response	☐	☐	☐	☐	☐	
3.10	Compile quotes from suppliers & subs into a bid or proposal package	☐	☐	☐	☐	☐	
3.11	Monitor the progress of fabricators	☐	☐	☐	☐	☐	
3.12	Plan the transportation routes of large items from the fabricator to the job site	☐	☐	☐	☐	☐	

3.13 Describe the most beneficial technologies used during *procurement* at your company:

Part 4.

Construction Management	Level 1	Level 2	Level 3
Degree of Technology Use	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
Characterization	Hardcopy → Human to human → "Give me a call" → Proximity is important →	Floppy disk → Human to machine → "Bring me a disk" → Proximity is less important →	Network Machine to machine "The file is on the network" Proximity is irrelevant
Example: Cost Estimate	Unit prices from a book Paper & pencil quantity survey Data manually entered into spreadsheet	Prices from stand-alone database Special software performs quantity survey on digitized drawings Enter data into estimating software	Estimating software linked electronically to CAD-based quantity survey & supplier prices Data automatically entered

ID	Task	Degree of Technology Use					If your process is more sophisticated than *Level 3*, please briefly describe that process:
		Don't Know	1	2	3	N/A	
4.01	Develop the construction schedule	☐	☐	☐	☐	☐	
4.02	Track field work progress & labor cost code charges	☐	☐	☐	☐	☐	
4.03	Maintain a daily job diary	☐	☐	☐	☐	☐	
4.04	Update the current cost forecast	☐	☐	☐	☐	☐	
4.05	Keep all project team members up to date on construction progress	☐	☐	☐	☐	☐	
4.06	Track the inventory of materials on site	☐	☐	☐	☐	☐	
4.07	Link field material managers to suppliers	☐	☐	☐	☐	☐	
4.08	Develop short-term work schedules based on labor, equipment, and material availability	☐	☐	☐	☐	☐	
4.09	Work crews submit and receive answers to Requests for Information (RFI's)	☐	☐	☐	☐	☐	
4.10	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule	☐	☐	☐	☐	☐	
4.11	Communicate design changes to field personnel	☐	☐	☐	☐	☐	
4.12	Communicate status of change orders to field	☐	☐	☐	☐	☐	
4.13	Update as-built drawings	☐	☐	☐	☐	☐	
4.14	Contractors submit requests for payment	☐	☐	☐	☐	☐	
4.15	Transfer funds from owner's account to contractor	☐	☐	☐	☐	☐	

4.16 Describe the most beneficial technologies used in *managing construction projects* at your company:

Part 5.

Construction Execution	Level 1	Level 2	Level 3
Degree of Technology Use	Labor intensive, little mechanization	Some mechanization	Mechanization linked with external information
Characterization	Human → Shovel → Laborer →	Machine assists human → Power shovel → Operator →	Human assists machine Intelligent power shovel Technician
Example: Hang sheet rock	Man-handle into place	Human guides machine to lift it into place	Machine linked to CAD model cuts and hangs with minimal assistance

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
5.01	Evaluate subsurface conditions	☐	☐	☐	☐	☐	________
5.02	Carry out earthwork and grading	☐	☐	☐	☐	☐	________
5.03	Construct rebar cages	☐	☐	☐	☐	☐	________
5.04	Weld pipes	☐	☐	☐	☐	☐	________
5.05	Select the appropriate crane for heavy lifts	☐	☐	☐	☐	☐	________
5.06	Provide an elevated work platform	☐	☐	☐	☐	☐	________
5.07	Fabricate roof trusses	☐	☐	☐	☐	☐	________
5.08	Manipulate and hang sheet rock	☐	☐	☐	☐	☐	________
5.09	Acquire & record laboratory test information	☐	☐	☐	☐	☐	________
5.10	Finish concrete surfaces	☐	☐	☐	☐	☐	________
5.11	Apply paint or coatings	☐	☐	☐	☐	☐	________

5.12 Describe the most beneficial technologies used in executing construction projects at your company:

5.13 Describe the most sophisticated technologies used in executing construction projects at your company:

Part 6. Start-up, Ops, & Maintenance	Level 1	Level 2	Level 3
Degree of Technology Use	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
Characterization	Hardcopy → Human to human → "Give me a call" → Proximity is important →	Floppy disk → Human to machine → "Bring me a disk" → Proximity is less important →	Network Machine to machine "The file is on the network" Proximity is irrelevant
Example: Maintenance Plan	Maintenance history in paper files Manufacturer data in paper files Plan written on word processor	Maintenance history in database Manufacturer data on disks Plan kept in stand-alone database	Database from the jobsite Manufacturer's data from a website Database linked to all operators

ID	Task	Degree of technology use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
6.01	Conduct pre-operations testing	☐	☐	☐	☐	☐	
6.02	Train facility operators (e.g. simulations, software)	☐	☐	☐	☐	☐	
6.03	Use as-built information in personnel training	☐	☐	☐	☐	☐	
6.04	Track & analyze the maintenance history of important equipment	☐	☐	☐	☐	☐	
6.05	Develop maintenance plans from maintenance history data	☐	☐	☐	☐	☐	
6.06	Monitor & assess equipment operations	☐	☐	☐	☐	☐	
6.07	Facility operators request maintenance or modifications	☐	☐	☐	☐	☐	
6.08	Update as-built drawings in response to facility modifications	☐	☐	☐	☐	☐	
6.09	Monitor/track/control facility energy usage	☐	☐	☐	☐	☐	
6.10	Monitor environmental impact of facility operations (e.g. air / water quality)	☐	☐	☐	☐	☐	

6.11 Describe the most beneficial technologies used in facility startup, operations, and maintenance at your company

Appendix C – Survey Version 2.1

09/21/98

Fax

To:		From:	
			University of Texas at Austin Dept of Civil Engineering
Fax:	( ) -	Fax:	(512) 471-3191
Phone:	( ) -	Phone:	(512) 471-
Re:	Automation & Integration Survey	Pages:	10+cover

☐ Urgent ☐ For Review ☐ Please Comment ☑ Please Reply

• **Comments:**

Please find attached a copy of the "Integration and Automation" Survey developed by the University of Texas' Sloan Program for the Construction Industry.

Please review this survey and return it by XXXX or at your earliest convenience. The form may be returned by fax or electronically to the individual below. Thank you in advance for your assistance.

Graduate Research Assistant
University of Texas at Austin

Phone: (512) 471-1620
Fax: (512) 471-
E-mail:

A Survey of Integration and Automation on Construction Projects

Version 2.1

Sloan Program for
the Construction Industry

The University of Texas at Austin

Directions

Purpose

The purpose of this survey is to assess the level of technology used on individual construction projects as well as to provide an understanding of the project's cost schedule and safety performance.

Directions

- Please complete the survey as directed bearing in mind that the survey should be answered in the context of a particular project. **All data will be held in strict confidence.**
- Feel free to answer only those questions for which you have a sufficient level of experience or knowledge. *It is not necessary to answer all questions*
- If you wish to complete a survey for more than one project, please contact the undersigned, and additional copies will be provided to you (or you may make copies of the blank survey in your possession).
- Please contact James T. O'Connor at (512) 471-4645 with any comments or questions.
- Survey results should be sent to the following address:

James T. O'Connor
Department of Civil Engineering
ECJ 5.200 M/C C1700
University of Texas
Austin, TX 78712

Fax: (512) 471-3191
e-mail: jtoconnor@mail.utexas.edu

Contact Information

Contact Name:

Phone Number:	**Fax Number:**	**E-mail Address:**
( ) -	( ) -	

Contact's Perspective: *which of the categories below best describes your perspective of the project?*

- ☐ Business Unit (project initiator, investor, senior management)
- ☐ Project Team (responsible for delivering an operational facility)
- ☐ Operations (responsible for operation of the completed facility)

Experience: *how many years of experience have you had in this position?* ☐ <5 ☐ 5-10 ☐ 10-20 ☐ >20

Company Information

Company Name:

Company Type:

- ☐ Public Owner
- ☐ Private Owner
- ☐ Design Consultant or A/E
- ☐ Prime Contractor or GC
- ☐ Design-Build or EPC
- ☐ Supplier or Fabricator
- ☐ Subcontractor
- Other (please describe): ______________________

Company Size:

Owners ($ Annual Capital Budget): ______________________

A/E's & Contractors ($ Annual Sales Volume): ______________________

Project Information

Project Name *not required, for reference only*

Project I.D. *You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and CII/Sloan personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries*

Project Location:

Domestic ____________________
State (U.S.)

International ____________________
Country

Project Type: *of the project types listed below, which best describes your project?*

Industrial
- ☐ Foods
- ☐ Pharmaceuticals Mfg.
- ☐ Consumer Products Mfg.
- ☐ Automotive
- ☐ Microelectronics Mfg.
- ☐ Pulp and Paper
- ☐ Power Generation
- ☐ Petroleum Refining
- ☐ Chemical Mfg.
- ☐ Oil & Gas Production
- ☐ Environmental / Remediation
- ☐ Metals Refining/Processing

Infrastructure
- ☐ Water/Wastewater
- ☐ Electrical Distribution / Communications
- ☐ Tunneling
- ☐ Highway
- ☐ Airport
- ☐ Rail
- ☐ Flood Control
- ☐ Navigation
- ☐ Marine Facilities
- ☐ Mining
- ☐ Solid Waste Management

Buildings
- ☐ Single-unit Residential
- ☐ Multi-unit Residential (low-rise)
- ☐ Multi- unit Residential (mid-rise and high-rise)
- ☐ Hotel / Motel
- ☐ Low-rise Office
- ☐ Mid-rise Office
- ☐ High-rise Office
- ☐ Retail
- ☐ Parking Garage
- ☐ Warehouse
- ☐ Educational
- ☐ Hospital / Clinic
- ☐ Laboratory
- ☐ Correctional
- ☐ Entertainment

Other: *(please specify)* ____________________

Cost Performance:

Total Installed Cost: ☐ <\$5 Million ☐ \$5-20 Million ☐ \$20-50 Million ☐ \$50-100 Million ☐ >\$100 Million

The total installed cost of the project was...
- ☐ Significantly under authorized Budget
- ☐ Essentially the same as Authorized Budget
- ☐ Significantly over Authorized Budget

After 4-6 months of operations, the operating cost of the facility was . . .
- ☐ Nominal
- ☐ Higher than anticipated
- ☐ Don't know

Schedule Performance:

Project Completion Date: __________ ☐ actual ☐ projected

The actual project completion date was...
- ☐ Significantly earlier than planned
- ☐ Essentially the same as the planned
- ☐ Significantly later than planned

The actual operations start date was...
- ☐ Significantly earlier than planned at authorization
- ☐ Essentially at the planned start date
- ☐ Significantly later than planned at authorization

Safety: *were there any OSHA reportable injuries during the project?*
- ☐ Yes
- ☐ No
- ☐ Don't know

Stakeholder Success: *e.g. owner, A/E, contractor, etc.*
- ☐ All project stakeholders shared in project success
- ☐ Nearly all project stakeholders shared in project success
- ☐ Only some project stakeholders shared in project success

Part 1. Front End

Degree of Technology Use	Level 1		Level 2		Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	---->	Specialized, stand-alone electronic tools	---->	Integrated electronic tools
	Hand written data	---->	Data in electronic format	---->	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	---->	Electronic data entered numerous times	---->	Single entry of data / re-cycling of data
	Human to human		------------------------>		Machine to machine
	Proximity important to information transfer		------------------------>		Proximity is irrelevant
Example: Needs Analysis	Traffic counting machines gather data, which is collected periodically and stored in paper files.		Traffic data is stored in a stand-alone GIS database, which is updated periodically.		GIS database linked to citywide sensor network displays real-time traffic data and trends.

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process
1.01	Conduct market analysis or need analysis for a new facility	☐	☐	☐	☐	☐	
1.02	Develop, evaluate, and refine the project's scope of work	☐	☐	☐	☐	☐	
1.03	Diagram the manufacturing process -or- the user's processes ("bubble diagram")	☐	☐	☐	☐	☐	
1.04	Estimate a budget from the scope of work	☐	☐	☐	☐	☐	
1.05	Develop a milestone schedule from the scope of work	☐	☐	☐	☐	☐	
1.06	Acquire and store site investigation data for use during design	☐	☐	☐	☐	☐	

1.07 Describe the most beneficial technologies used in *front-end* processes at your company:

Part 2. Design

Degree of Technology Use	Level 1		Level 2		Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	------>	Specialized, stand-alone electronic tools	------>	Integrated electronic tools
	Hand written data	------>	Data in electronic format	------>	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	------>	Electronic data entered numerous times	------>	Single entry of data / re-cycling of data
	Human to human		------------------------------->		Machine to machine
	Proximity important to information transfer		------------------------------->		Proximity is irrelevant
Example: Design Structural System	Designer gets loads from a manual; puts a concept on paper; passes to a draftsman who draws by hand. Details are cut and pasted on drawings.		Designer gets loads from stand-alone software; puts a concept on CAD and gives the disk to a CAD technician for details		Designers from all disciplines collaborate on a network with a common CAD model. Details automatically added from database

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
2.01	Designers access supplier information in order to select components	☐	☐	☐	☐	☐	
2.02	Get input from operators and builders regarding construction methods selection, & construction sequencing	☐	☐	☐	☐	☐	
2.03	Analyze alternative construction methods for effects on cost, schedule, etc.	☐	☐	☐	☐	☐	
2.04	Use conceptual design work as a basis for detailed design work	☐	☐	☐	☐	☐	
2.05	Generate facility floor plans	☐	☐	☐	☐	☐	
2.06	Design the fluid transport system (open channel or pipes) and related drawings	☐	☐	☐	☐	☐	
2.07	Design the structural system and related drawings	☐	☐	☐	☐	☐	
2.08	Design the electrical system and related drawings	☐	☐	☐	☐	☐	
2.09	Design the HVAC system and prepare related drawings	☐	☐	☐	☐	☐	
2.10	Document the assumptions used in developing the budget, and pass to the next phase	☐	☐	☐	☐	☐	
2.11	Detect physical interference between systems (i.e. plumbing, electrical, structural, etc.)	☐	☐	☐	☐	☐	
2.12	Prepare project specifications	☐	☐	☐	☐	☐	
2.13	Check the design against owner requirements (e.g. design reviews) and code requirements	☐	☐	☐	☐	☐	
2.14	Track design progress	☐	☐	☐	☐	☐	

2.15 Describe the most <u>beneficial</u> technologies used during *detailed design* at your company:

Part 3. Procurement

Degree of Technology Use	Level 1		Level 2		Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	----->	Specialized, stand-alone electronic tools	----->	Integrated electronic tools
	Hand written data	----->	Data in electronic format	----->	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	----->	Electronic data entered numerous times	----->	Single entry of data / re-cycling of data
	Human to human		----------------------------->		Machine to machine
	Proximity important to information transfer		----------------------------->		Proximity is irrelevant
Example: Bid Proposal	• Get paper copies of drawings/specs • Input the prices in a spreadsheet • Hand a hard copy of proposal to owner		• Get CD-ROM files of CAD model • Compile bid with special software • Give owner a disk copy of proposal		• Download CAD files from network • Obtain bids from subs electronically • Transmit file via network to owner

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
3.01	Determine the lead time required to order equipment and materials	☐	☐	☐	☐	☐	
3.02	Conduct a quantity survey of drawings	☐	☐	☐	☐	☐	
3.03	Link quantity survey data to the cost estimating process	☐	☐	☐	☐	☐	
3.04	Link supplier cost quotes to the cost estimating process	☐	☐	☐	☐	☐	
3.05	Refine the preliminary budget estimate	☐	☐	☐	☐	☐	
3.06	Develop the milestone schedule	☐	☐	☐	☐	☐	
3.07	Develop and transmit requests for proposal to suppliers and subs	☐	☐	☐	☐	☐	
3.08	Prepare & submit shop drawings	☐	☐	☐	☐	☐	
3.09	Acquire & review shop drawings; send response	☐	☐	☐	☐	☐	
3.10	Compile quotes from suppliers & subs into a bid or proposal package	☐	☐	☐	☐	☐	
3.11	Monitor the progress of fabricators	☐	☐	☐	☐	☐	
3.12	Plan the transportation routes of large items from the fabricator to the job site	☐	☐	☐	☐	☐	

3.13 Describe the most <u>beneficial</u> technologies used during *procurement* at your company:

Part 4. Construction Management

Degree of Technology Use	Level 1		Level 2		Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	----->	Specialized, stand-alone electronic tools	----->	Integrated electronic tools
	Hand written data	----->	Data in electronic format	----->	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	----->	Electronic data entered numerous times	----->	Single entry of data / re-cycling of data
	Human to human		------------------------->		Machine to machine
	Proximity important to information transfer		------------------------->		Proximity is irrelevant
Example: Cost Estimate	• Unit prices from a book • Paper & pencil quantity survey		• Prices from stand-alone database • Special software performs quantity survey on digitized drawings		• Estimating software linked electronically to CAD-based quantity survey & supplier prices
	• Data manually entered into spreadsheet		• Enter data into estimating software		• Data automatically entered

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
4.01	Develop the construction schedule	☐	☐	☐	☐	☐	
4.02	Track field work progress & labor cost code charges	☐	☐	☐	☐	☐	
4.03	Maintain a daily job diary	☐	☐	☐	☐	☐	
4.04	Update the current cost forecast	☐	☐	☐	☐	☐	
4.05	Keep all project team members up to date on construction progress	☐	☐	☐	☐	☐	
4.06	Track the inventory of materials on site	☐	☐	☐	☐	☐	
4.07	Link field material managers to suppliers	☐	☐	☐	☐	☐	
4.08	Develop short-term work schedules based on labor, equipment, and material availability	☐	☐	☐	☐	☐	
4.09	Work crews submit and receive answers to Requests for Information (RFI's)	☐	☐	☐	☐	☐	
4.10	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule	☐	☐	☐	☐	☐	
4.11	Communicate design changes to field personnel	☐	☐	☐	☐	☐	
4.12	Communicate status of change orders to field	☐	☐	☐	☐	☐	
4.13	Update as-built drawings	☐	☐	☐	☐	☐	
4.14	Contractors submit requests for payment	☐	☐	☐	☐	☐	
4.15	Transfer funds from owner's account to contractor	☐	☐	☐	☐	☐	

4.16 Describe the most beneficial technologies used in *managing construction projects* at your company:

Part 5. Construction Execution

Degree of Technology Use	Level 1		Level 2		Level 3
Characteristics	Labor intensive, little mechanization	--->	Some mechanization	--->	Mechanization linked with external information
	Human	--->	Machine assists human	--->	Human assists machine
	Laborer	--->	Operator	--->	Technician
Example: Hang sheet rock	• Manual placement		• Human guides machine to lift it into place		• Machine linked to CAD model cuts and hangs with minimal assistance
Site preparation	• Shovel		• Grader		• Grader linked to GPS

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
5.01	Evaluate subsurface conditions	☐	☐	☐	☐	☐	
5.02	Carry out earthwork and grading	☐	☐	☐	☐	☐	
5.03	Construct rebar cages	☐	☐	☐	☐	☐	
5.04	Weld pipes	☐	☐	☐	☐	☐	
5.05	Select the appropriate crane for heavy lifts	☐	☐	☐	☐	☐	
5.06	Provide an elevated work platform	☐	☐	☐	☐	☐	
5.07	Fabricate roof trusses	☐	☐	☐	☐	☐	
5.08	Manipulate and hang sheet rock	☐	☐	☐	☐	☐	
5.09	Acquire & record laboratory test information	☐	☐	☐	☐	☐	
5.10	Finish concrete surfaces	☐	☐	☐	☐	☐	
5.11	Apply paint or coatings	☐	☐	☐	☐	☐	

5.12 Describe the most beneficial technologies used in executing construction projects at your company:

Part 6. Start-up, Operations & Maintenance

Degree of Technology Use	Level 1		Level 2		Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	--->	Specialized, stand-alone electronic tools	--->	Integrated electronic tools
	Hand written data	--->	Data in electronic format	--->	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	--->	Electronic data entered numerous times	--->	Single entry of data / re-cycling of data
	Human to human		--------------------------->		Machine to machine
	Proximity important to information transfer		--------------------------->		Proximity is irrelevant
Example: Maintenance Plan	• Maintenance history in paper files		• Maintenance history in database		• Database from the job site
	• Manufacturer data in paper files		• Manufacturer data on disks		• Manufacturer's data from a web site
	• Plan written on word processor		• Plan kept in stand-alone database		• Database linked to all operators

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	If your process is more sophisticated than *Level 3*, please briefly describe that process:
6.01	Conduct pre-operations testing	☐	☐	☐	☐	☐	
6.02	Train facility operators (e.g. simulations, software)	☐	☐	☐	☐	☐	
6.03	Use as-built information in personnel training	☐	☐	☐	☐	☐	
6.04	Track & analyze the maintenance history of important equipment	☐	☐	☐	☐	☐	
6.05	Develop maintenance plans from maintenance history data	☐	☐	☐	☐	☐	
6.06	Monitor & assess equipment operations	☐	☐	☐	☐	☐	
6.07	Facility operators request maintenance or modifications	☐	☐	☐	☐	☐	
6.08	Update as-built drawings in response to facility modifications	☐	☐	☐	☐	☐	
6.09	Monitor/track/control facility energy usage	☐	☐	☐	☐	☐	
6.10	Monitor environmental impact of facility operations (e.g. air / water quality)	☐	☐	☐	☐	☐	

6.11 Describe the most <u>beneficial</u> technologies used in facility startup, operations, and maintenance at your company

Appendix D – Survey Version 2.2

A SURVEY OF
INTEGRATION AND AUTOMATION
ON CONSTRUCTION PROJECTS

VERSION 2.2

SLOAN PROGRAM FOR
THE CONSTRUCTION INDUSTRY

THE UNIVERSITY OF TEXAS AT AUSTIN

Directions

Purpose

The purpose of this survey is to assess the level of technology used on individual construction projects as well as to provide an understanding of the project's cost schedule and safety performance.

Directions

- Please complete the survey as directed bearing in mind that the survey should be answered in the context of a particular project. **All data will be held in strict confidence.**
- Feel free to answer only those questions for which you have a sufficient level of experience or knowledge. *It is not necessary to answer all questions*
- If you wish to complete a survey for more than one project, please contact the undersigned, and additional copies will be provided to you (or you may make copies of the blank survey in your possession).
- Please contact James T. O'Connor at (512) 471-4645 with any comments or questions.
- Survey results should be sent to the following address:

James T. O'Connor
Department of Civil Engineering
ECJ 5.200 M/C C1700
University of Texas
Austin, TX 78712

Fax: (512) 471-3191
e-mail: jtoconnor@mail.utexas.edu

Contact Information

Contact Name:

Phone Number: ( ) -

Fax Number: ( ) -

E-mail Address:

Contact's Perspective: *which of the categories below best describes your perspective of the project?*

- ☐ Business Unit (project initiator, investor, senior management)
- ☐ Project Team (responsible for delivering an operational facility)
- ☐ Operations (responsible for operation of the completed facility)

Experience: *how many years of experience have you had in this position?* ☐ <5 ☐ 5-10 ☐ 10-20 ☐ >20

Company Information

Company Name:

Company Type:

- ☐ Public Owner
- ☐ Private Owner
- ☐ Design Consultant or A/E
- ☐ Prime Contractor or GC
- ☐ Design-Build or EPC
- ☐ Supplier or Fabricator
- ☐ Subcontractor
- Other (please describe):____________________

Company Size:

Owners ($ Annual Capital Budget): ____________________

A/E's & Contractors ($ Annual Sales Volume): ____________________

Project Information

Project Name:

Project Location:

Domestic ____________________ State (U.S.)

International ____________________ Country

Project I.D. *You may use any reference to protect the project's identity. The purpose of this I.D. is to help you and CII/Sloan personnel identify the questionnaire correctly if clarification of data is needed and to prevent duplicate project entries*

Project Completion Date: __________ ☐ actual ☐ projected

Total Installed Cost: ☐ <$5 Million ☐ $5-20 Million ☐ $20-50 Million ☐ $50-100 Million ☐ >$100 Million

Project Nature: ☐ "Green Field" ☐ Renovation ☐ Expansion

Project Information (continued)

Project Type: *of the project types listed below, which best describes your project?*

<u>Industrial</u>
- ☐ Foods
- ☐ Pharmaceuticals Mfg.
- ☐ Consumer Products Mfg.
- ☐ Automotive
- ☐ Microelectronics Mfg.
- ☐ Pulp and Paper
- ☐ Power Generation
- ☐ Petroleum Refining
- ☐ Chemical Mfg.
- ☐ Oil & Gas Production
- ☐ Environmental / Remediation
- ☐ Metals Refining/Processing

<u>Infrastructure</u>
- ☐ Water/Wastewater
- ☐ Electrical Distribution / Communications
- ☐ Tunneling
- ☐ Highway
- ☐ Airport
- ☐ Rail
- ☐ Flood Control
- ☐ Navigation
- ☐ Marine Facilities
- ☐ Mining
- ☐ Solid Waste Management

<u>Buildings</u>
- ☐ Single-unit Residential
- ☐ Multi-unit Residential (low-rise)
- ☐ Multi- unit Residential (mid-rise and high-rise)
- ☐ Hotel / Motel
- ☐ Low-rise Office
- ☐ Mid-rise Office
- ☐ High-rise Office
- ☐ Retail
- ☐ Parking Garage
- ☐ Warehouse
- ☐ Educational
- ☐ Hospital / Clinic
- ☐ Laboratory
- ☐ Correctional
- ☐ Entertainment

Other: *(please specify)* ____________________________

Cost Performance:

The <u>total installed cost</u> of the project was...
- ☐ Significantly <u>under</u> authorized Budget
- ☐ Essentially <u>the same as</u> Authorized Budget
- ☐ Significantly <u>over</u> Authorized Budget

After 4-6 months of operations, the <u>operating cost</u> of the facility was...
- ☐ A problem
- ☐ Not a problem
- ☐ Don't know

Schedule Performance:

The <u>actual project completion date</u> was...
- ☐ Significantly <u>earlier than</u> planned
- ☐ Essentially <u>the same as</u> the planned
- ☐ Significantly <u>later than</u> planned

The <u>actual operations start date</u> was...
- ☐ Significantly <u>earlier than</u> planned at authorization
- ☐ Essentially <u>at</u> the planned start date
- ☐ Significantly <u>later than</u> planned at authorization

Safety: *were there any OSHA reportable injuries during the project?*
- ☐ Yes
- ☐ No
- ☐ Don't know

Stakeholder Success: *e.g. owner, A/E, contractor, etc.*
- ☐ All project stakeholders shared in project success
- ☐ Nearly all project stakeholders shared in project success
- ☐ Only some project stakeholders shared in project success

Can a significant portion of the project outcome be credited to (or blamed on) the use of technology? ☐ Yes ☐ No

How does the degree of technology use on this project compare with other projects your company has participated in?

☐ Typical ☐ Advanced

Part 1. Front End

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Needs Analysis	Traffic counting machines gather data, which is collected periodically and stored in paper files.	Traffic data is stored in a stand-alone GIS database, which is updated periodically.	GIS database linked to citywide sensor network displays real-time traffic data and trends.

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
1.01	Conduct market analysis or need analysis for a new facility	☐	☐	☐	☐	☐	
1.02	Develop, evaluate, and refine the project's scope of work	☐	☐	☐	☐	☐	
1.03	Diagram the manufacturing process -or- the user's processes ("bubble diagram")	☐	☐	☐	☐	☐	
1.04	Estimate a budget from the scope of work	☐	☐	☐	☐	☐	
1.05	Develop a milestone schedule from the scope of work	☐	☐	☐	☐	☐	
1.06	Acquire and store site investigation data for use during design	☐	☐	☐	☐	☐	

1.07 Describe the most beneficial technologies used in *front-end* processes at your company:

Part 2. Design

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Design Structural System	Designer gets loads from a manual; puts a concept on paper; passes to a draftsman who draws by hand. Details are cut and pasted on drawings.	Designer gets loads from stand-alone software; puts a concept on CAD and gives the disk to a CAD technician for details	Designers from all disciplines collaborate on a network with a common CAD model. Details automatically added from database

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
2.01	Designers access supplier information in order to select components	☐	☐	☐	☐	☐	
2.02	Get input from operators and builders regarding construction methods selection, & construction sequencing	☐	☐	☐	☐	☐	
2.03	Analyze alternative construction methods for effects on cost, schedule, etc.	☐	☐	☐	☐	☐	
2.04	Use conceptual design work as a basis for detailed design work	☐	☐	☐	☐	☐	
2.05	Generate facility floor plans	☐	☐	☐	☐	☐	
2.06	Design the fluid transport system (open channel or pipes) and related drawings	☐	☐	☐	☐	☐	
2.07	Design the structural system and related drawings	☐	☐	☐	☐	☐	
2.08	Design the electrical system and related drawings	☐	☐	☐	☐	☐	
2.09	Design the HVAC system and prepare related drawings	☐	☐	☐	☐	☐	
2.10	Document the assumptions used in developing the budget, and pass to the next phase	☐	☐	☐	☐	☐	
2.11	Detect physical interference between systems (i.e. plumbing, electrical, structural, etc.)	☐	☐	☐	☐	☐	
2.12	Prepare project specifications	☐	☐	☐	☐	☐	
2.13	Check the design against owner requirements (e.g. design reviews) and code requirements	☐	☐	☐	☐	☐	
2.14	Track design progress	☐	☐	☐	☐	☐	

2.15 Describe the most beneficial technologies used during *detailed design* at your company:

Part 3. Procurement

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools Hand written data Verbal or paper data transfer / little or no re-use of data Human to human Proximity important to information transfer	Specialized, stand-alone electronic tools Data in electronic format Electronic data entered numerous times	Integrated electronic tools Shared electronic data (e.g. network) Single entry of data / re-cycling of data Machine to machine Proximity is irrelevant
<u>Example:</u> Bid Proposal	• Get paper copies of drawings/specs • Input the prices in a spreadsheet • Hand a hard copy of proposal to owner	• Get CD-ROM files of CAD model • Compile bid with special software • Give owner a disk copy of proposal	• Download CAD files from network • Obtain bids from subs electronically • Transmit file via network to owner

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
3.01	Determine the lead time required to order equipment and materials	☐	☐	☐	☐	☐	
3.02	Conduct a quantity survey of drawings	☐	☐	☐	☐	☐	
3.03	Link quantity survey data to the cost estimating process	☐	☐	☐	☐	☐	
3.04	Link supplier cost quotes to the cost estimating process	☐	☐	☐	☐	☐	
3.05	Refine the preliminary budget estimate	☐	☐	☐	☐	☐	
3.06	Develop the milestone schedule	☐	☐	☐	☐	☐	
3.07	Develop and transmit requests for proposal to suppliers and subs	☐	☐	☐	☐	☐	
3.08	Prepare & submit shop drawings	☐	☐	☐	☐	☐	
3.09	Acquire & review shop drawings; send response	☐	☐	☐	☐	☐	
3.10	Compile quotes from suppliers & subs into a bid or proposal package	☐	☐	☐	☐	☐	
3.11	Monitor the progress of fabricators	☐	☐	☐	☐	☐	
3.12	Plan the transportation routes of large items from the fabricator to the job site	☐	☐	☐	☐	☐	

3.13 Describe the most <u>beneficial</u> technologies used during *procurement* at your company:

Part 4. Construction Management

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools Hand written data Verbal or paper data transfer / little or no re-use of data Human to human Proximity important to information transfer	Specialized, stand-alone electronic tools Data in electronic format Electronic data entered numerous times	Integrated electronic tools Shared electronic data (e.g. network) Single entry of data / re-cycling of data Machine to machine Proximity is irrelevant
Example: Cost Estimate	• Unit prices from a book • Paper & pencil quantity survey	• Prices from stand-alone database • Special software performs quantity survey on digitized drawings	• Estimating software linked electronically to CAD-based quantity survey & supplier prices
	• Data manually entered into spreadsheet	• Enter data into estimating software	• Data automatically entered

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
4.01	Develop the construction schedule	☐	☐	☐	☐	☐	
4.02	Track field work progress & labor cost code charges	☐	☐	☐	☐	☐	
4.03	Maintain a daily job diary	☐	☐	☐	☐	☐	
4.04	Update the current cost forecast	☐	☐	☐	☐	☐	
4.05	Keep all project team members up to date on construction progress	☐	☐	☐	☐	☐	
4.06	Track the inventory of materials on site	☐	☐	☐	☐	☐	
4.07	Link field material managers to suppliers	☐	☐	☐	☐	☐	
4.08	Develop short-term work schedules based on labor, equipment, and material availability	☐	☐	☐	☐	☐	
4.09	Work crews submit and receive answers to Requests for Information (RFI's)	☐	☐	☐	☐	☐	
4.10	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule	☐	☐	☐	☐	☐	
4.11	Communicate design changes to field personnel	☐	☐	☐	☐	☐	
4.12	Communicate status of change orders to field	☐	☐	☐	☐	☐	
4.13	Update as-built drawings	☐	☐	☐	☐	☐	
4.14	Contractors submit requests for payment	☐	☐	☐	☐	☐	
4.15	Transfer funds from owner's account to contractor	☐	☐	☐	☐	☐	

4.16 Describe the most beneficial technologies used in *managing construction projects* at your company:

Part 5. Construction Execution

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	Labor intensive, little mechanization Human Laborer	Some mechanization Machine assists human Operator	Mechanization linked with external information Human assists machine Technician
Example: Hang sheet rock Site preparation	• Manual placement • Shovel	• Human guides machine to lift it into place • Grader	• Machine linked to CAD model cuts and hangs with minimal assistance • Grader linked to GPS

ID	Task	Degree of Technology Use					Comments
		Don't Know	1	2	3	N/A	
5.01	Evaluate subsurface conditions	☐	☐	☐	☐	☐	
5.02	Carry out earthwork and grading	☐	☐	☐	☐	☐	
5.03	Construct rebar cages	☐	☐	☐	☐	☐	
5.04	Weld pipes	☐	☐	☐	☐	☐	
5.05	Select the appropriate crane for heavy lifts	☐	☐	☐	☐	☐	
5.06	Provide an elevated work platform	☐	☐	☐	☐	☐	
5.07	Fabricate roof trusses	☐	☐	☐	☐	☐	
5.08	Manipulate and hang sheet rock	☐	☐	☐	☐	☐	
5.09	Acquire & record laboratory test information	☐	☐	☐	☐	☐	
5.10	Finish concrete surfaces	☐	☐	☐	☐	☐	
5.11	Apply paint or coatings	☐	☐	☐	☐	☐	

5.12 Describe the most <u>beneficial</u> technologies used in executing construction projects at your company:

Part 6. Start-up, Operations & Maintenance

Degree of Technology Use	Level 1	Level 2	Level 3
Characteristics	No electronic tools -or- Commonly-used electronic tools	Specialized, stand-alone electronic tools	Integrated electronic tools
	Hand written data	Data in electronic format	Shared electronic data (e.g. network)
	Verbal or paper data transfer / little or no re-use of data	Electronic data entered numerous times	Single entry of data / re-cycling of data
	Human to human		Machine to machine
	Proximity important to information transfer		Proximity is irrelevant
Example: Maintenance Plan	• Maintenance history in paper files	• Maintenance history in database	• Database from the job site
	• Manufacturer data in paper files	• Manufacturer data on disks	• Manufacturer's data from a web site
	• Plan written on word processor	• Plan kept in stand-alone database	• Database linked to all operators

ID	Task	Degree of Technology Use: Don't Know	1	2	3	N/A	Comments
6.01	Conduct pre-operations testing	☐	☐	☐	☐	☐	
6.02	Train facility operators (e.g. simulations, software)	☐	☐	☐	☐	☐	
6.03	Use as-built information in personnel training	☐	☐	☐	☐	☐	
6.04	Track & analyze the maintenance history of important equipment	☐	☐	☐	☐	☐	
6.05	Develop maintenance plans from maintenance history data	☐	☐	☐	☐	☐	
6.06	Monitor & assess equipment operations	☐	☐	☐	☐	☐	
6.07	Facility operators request maintenance or modifications	☐	☐	☐	☐	☐	
6.08	Update as-built drawings in response to facility modifications	☐	☐	☐	☐	☐	
6.09	Monitor/track/control facility energy usage	☐	☐	☐	☐	☐	
6.10	Monitor environmental impact of facility operations (e.g. air / water quality)	☐	☐	☐	☐	☐	

6.11 Describe the most beneficial technologies used in facility startup, operations, and maintenance at your company

Appendix E – Changes from Version 2.0 to 2.1

Change	Description	Page	Reason
Added	Cover Page	--	Gives the package a professional look
Added	Purpose and Directions	--	Responding to common questions raised by participants
Moved	Project Information to its own page	--	Separating respondent and project information relieves congestion
Added	Company Size Question – Owners ($ Annual Capital Budget) – A/E's & Contractors ($ Annual Sales Volume)	i	Allows project performance comparison
Added	Project Name (optional)	ii	Helps identify project if more data is required at a later date
Added	Project I.D.	ii	Helps identify the project and prevent duplication in the database
Added	Project Location	ii	Allows check of sample diversity
Added	"Multi-Unit Residential (mid-rise & high-rise)"project type	ii	Maintains consistency with "office" categories
Changed	"Medical" project type To: "Hospital/Clinic"	ii	Eliminates some potential ambiguity
Added	"Entertainment" project type	ii	Covers sports stadiums, theme parks, etc.
Added	"(please specify) and a line following the "Other" category	ii	Highlights the need for clarification
Added	Operating Cost performance measure	ii	Finer analysis of performance
Added	Project Completion Date	ii	Shows whether data is complete
Added	Actual Operations Start Date	ii	Finer analysis of performance
Added	Safety Success performance measure	ii	Finer analysis of performance
Added	Stakeholder Success performance measure	ii	Checks the potential for lopsided success across the project team

Change	Description	Page	Reason
Changed	Font size of project types to 10 point	ii	Conserves space for additional information
Added	Survey title, page number, and version number to footer	All	Avoids confusion during follow-up interviews
Changed	Font in the characterization table to 9 point	1-1, 2-1, 3-1, 4-1, 5-1, 6-1	Provides more room vertically and horizontally on the page
Changed	"Characterization" To: "Characteristics" on the second line of the characterization table	1-1, 2-1, 3-1, 4-1, 5-1, 6-1	Simplicity
Changed	Reformatted lines and arrows in the characterization table	1-1, 2-1, 3-1, 4-1, 5-1, 6-1	Aesthetics/ preferences
Changed	"Hardcopy, "Floppy disk", "Network" To: "Handwritten data", "Data in electronic format", "Shared electronic data (e.g. network)"	1-1, 2-1, 3-1, 4-1, 6-1	Sounds more professional
Deleted	"Human to machine"	1-1, 2-1, 3-1, 4-1, 6-1	No need to define the intermediate level between "Human to human" and "Machine to machine"
Changed	"'Give me a call'", "'Bring me a disk'", "'The file is on the network'" To: "Verbal or paper data transfer/ little or no re-use of data", "Electronic data entered numerous times", "Single entry of data/ re-cycling of data"	1-1, 2-1, 3-1, 4-1, 6-1	Sounds more professional

Change	Description	Page	Reason
Deleted	"Proximity is less important"	1-1, 2-1, 3-1, 4-1, 6-1	No need to define the intermediate level between "Proximity important" and "Proximity irrelevant"
Deleted	"Shovel", "Power shovel", "Intelligent power shovel" from characteristics	5-1	Fits better as an example than a characteristic
Added	"Shovel", Grader", "Grader linked to GPS" as a "Site preparation" example	5-1	Fits better as an example than a characteristic
Moved	Moved the section title from the characterization table into the header	1-1, 2-1, 3-1, 4-1, 5-1, 6-1	Conserves space vertically on the page
Deleted	"most beneficial technology" question	1-1, 5-1	Eliminates some redundancy

Appendix F – Changes from Version 2.1 to 2.2

Change	Description	Page	Reason
Added	"How does the degree of technology use on this project compare with other projects your company has participated in? ☐ Typical ☐ Advanced"	ii	Differentiates between best and average projects
Added	"Can a significant portion of the project outcome be credited to (or blamed on) the use of technology? ☐ Yes ☐ No"	ii	Checks for possible external factors that may have affected project outcome independent of technology use
Changed	Operating Cost Performance responses: "☐ Nominal" "☐ Higher than anticipated" To: "☐ A problem" "☐ Not a problem"	ii	Clarity and comprehensiveness
Added	"Project Nature: ☐ 'Green Field' ☐ Renovation ☐ Expansion"	ii	Allows check of correlation with degree of technology use
Changed	"If your process is more sophisticated than Level 3, please briefly describe that process" To: "Comments"	1-1, 2-1, 3-1, 4-1, 5-1, 6-1	Gives respondent more flexibility

Appendix G – Automation and Integration Technology Listing

Tech ID #	Technology	Applicable Phase/Task 1. Front End 2. Design 3. Procurement 4. Construction 5. Startup/Comm 6. Maint./Ops	Prime Benefit 1. Productivity 2. Cost 3. Schedule 4. Quality 5. Safety
C	**Communications**		
C.1	Conventional (memo, phone, video conferencing, E-mail)	All	All
C.2	Internet/intranet	--	--
C.2.1	Project Websites	1, 2, 3, 4, 5	All
C.2.2	Automated web-publishing	All	1, 2, 3
C.3	Large Bandwidth Data Transfer	--	--
C.3.1	ISDN, T1, Ethernet, Cable, Fiber-Optic	1, 2, 3, 4	All
C.4	Wireless Communication	--	--
C.4.1	Radio, Cellular, Satellite	All	All
C.5	Digital	All	1, 3, 4
C.6	Electronic Data Interchange (EDI)	All	1, 2, 3, 4
C.7	Data transfer standards	--	--
C.7.1	STEP	1, 2, 3, 4	All
C.7.2	International Alliance for Interoperability (IAI)--Industry Foundation Classes	1, 2, 3, 4	All
H	**Hardware**		
H.1	Client-server	All	All
H.2	"Robust" technologies	4, 6	1, 2, 3, 4
H.3	Increased power and use of current personal computing	All	All
H.4	Personal digital assistants (PDA)	4, 5	1
H.5	Global Position System (GPS) related	4	1, 2, 3, 4

Tech ID #	Technology	Applicable Phase/Task 1. Front End 2. Design 3. Procurement 4. Construction 5. Startup/Comm 6. Maint./Ops	Prime Benefit 1. Productivity 2. Cost 3. Schedule 4. Quality 5. Safety
H.6	Wireless devices	All	1
H.6.1	Remote laptop linked to project database and schedule information	4	1, 2, 3, 4
S	**Software**		
S.1	CAD	--	--
S.2.1	2-D	2, 3	1, 4
S.2.2	3-D with no attribute database	2, 3, 4	1, 4
S.2.3	3-D with attribute database	2, 3, 4	1, 3, 4
S.2.4	3-D linked to object-oriented knowledge	All	1, 2, 3, 4
S.2.5	3-D with timed replay/linked with schedule program	2, 3, 4, 5	All
S.2.6	CAD compatibility and links with suppliers	2, 3, 4	All
S.2.7	Compatible, CAD-based shop drawings and submittals	3, 4	All
S.2.8	User-defined CAD images accessible at jobsite	4, 5, 6	All
S.3	Scheduling	2, 3, 4, 5	All
S.4	Estimating/Costing	All	2
S.5	Document Management Systems	All	1, 4
S.6	Middleware	All	All
S.7	Visualization Technologies	All	2, 3
S.7.1	On the Internet (VRML)	--	--
S.7.2	Virtual Reality	--	--
S.7.3	Walk-thru	--	--
S.8	Artificial Intelligence (AI)	All	2, 3, 4

Tech ID #	Technology	Applicable Phase/Task 1. Front End 2. Design 3. Procurement 4. Construction 5. Startup/Comm 6. Maint./Ops	Prime Benefit 1. Productivity 2. Cost 3. Schedule 4. Quality 5. Safety
S.9	Knowledge-based engineering (KBE)	1, 2	2, 3, 4
S.10	Autonomous agents	1,2,3	1, 2, 3
D	**Data Structures**		
D.1	Data warehouses	3, 6	1, 3
D.2	Data marts	3, 6	1, 3
D.3	Relational Databases, Relational Database Management Systems (RDBMS)	All	All
D.4	Object-Oriented Technologies/Databases	All	All
MS	**Modeling and Simulation**		
MS.1	Dumb organization chart vs. organization chart linked to activity model	All	All
MS.2	Simulation of technology implementation (ABC-Sim)	All	All
WL	**Function Wish List**		
WL.1	Corporate/project lessons learned databases. Project archiving.	All	All
WL.1.1	Non-existent	--	--
WL.1.2	Hard copy only	--	--
WL.1.3	CD ROM-based	--	--
WL.1.4	On intranet or network	--	--
WL.1.5	Linked to other computerized knowledge bases (standards, etc.)	--	--
WL.2	Intelligent P&ID's	--	--
WL.2.1	Conventional	2, 3, 4, 5	Baseline

Tech ID #	Technology	Applicable Phase/Task 1. Front End 2. Design 3. Procurement 4. Construction 5. Startup/Comm 6. Maint./Ops	Prime Benefit 1. Productivity 2. Cost 3. Schedule 4. Quality 5. Safety
WL.2.2	Automated generation of equipment lists, instrument lists, piping line lists	2, 3, 4, 5, 6	1, 2, 3, 4
WL.2.3	Automated generation of systems lists	2, 3, 4, 5	1, 2, 3, 4
WL.2.4	Tracks operating properties (flow rates, temperatures, etc.)	5, 6	2, 4, 6
WL.3	Automatic as-built data collection and assessment	4, 5	2, 4
WL.4	Efficient Pipe design	--	--
WL.4.1	Automated routing/alternatives assessment	2, 4	1, 2, 3, 4
WL.4.2	Automated drawing generation/automatic link to CAD	2, 3, 4	1, 2, 3, 4
WL.4.3	Automated parts list/bill of materials/cost estimates generation	2, 3, 4	1, 2, 3, 4
WL.4.4	Electronic transfer of piping drawings to pipe fabricator	2, 3, 4	1, 2, 3, 4
WL.5	Electrical/instrumentation routing	2, 4, 6	1, 2
WL.6	Structural steel design linked to CAD	2, 3, 4	1, 2
WL.7	On-line package units catalogues	2, 3	1
WL.8	Project specification system	2, 3, 4	1, 4
WL.8.1	Dumb word processing only	--	--
WL.8.2	Smart word processing with identification of variables	--	--
WL.8.2	Smart database approach	--	--
WL.8.4	Smart linked-object approach	--	--
WL.8.4.1	Linked to CAD	--	--

Tech ID #	Technology	Applicable Phase/Task 1. Front End 2. Design 3. Procurement 4. Construction 5. Startup/Comm 6. Maint./Ops	Prime Benefit 1. Productivity 2. Cost 3. Schedule 4. Quality 5. Safety
WL.8.4.2	Linked to procurement system (bid tabs, PO's, etc.)	--	--
WL.8.4.3	Linked to field QA/QC system	--	--
WL.9	Schedule management	--	--
WL.9.1	All-manual, no CPM	1, 2, 3, 4	1, 2, 3
WL.9.2	Computerized CPM	1, 2, 3, 4	1, 2, 3
WL.9.3	With Resource loading	1, 2, 3, 4	1, 2, 3
WL.9.4	With probabilistic time estimates	1, 2, 3, 4	1, 2, 3
WL.9.5	Linked to cost tracking/control	1, 2, 3, 4	1, 2, 3
WL.9.6	Linked to CAD	1, 2, 3, 4	1, 2, 3
WL.9.7	Linked to organization chart	1, 2, 3, 4	1, 2, 3
WL.10	Materials management	--	--
WL.10.1	CAD with material take-off capability	2, 3, 4, 6	1
WL.10.2	Partial inventory computer database	3, 4, 6	1, 2, 3
WL.10.3	Complete inventory database	3, 4, 6	1, 2, 3
WL.10.4	Field bar-coding of components	4, 5, 6	1, 2, 3
WL.11	Bid tabulation soliciting and generation using EDI	2, 3, 4	1, 3, 4
WL.12	Purchase order transfer using EDI	3, 4, 6	1,2,3,4
WL.13	Fabrication expediting and statusing using EDI	3, 4, 6	1,2,3,4
WL.14	QA/QC sampling—statistical process control	2, 3, 4, 6	4
WL.15	Real-time site configuration using CAD linked with schedule	4	All
WL.16	Instrumentation calibration and documentation	4, 5, 6	4

Tech ID #	Technology	Applicable Phase/Task 1. Front End 2. Design 3. Procurement 4. Construction 5. Startup/Comm 6. Maint./Ops	Prime Benefit 1. Productivity 2. Cost 3. Schedule 4. Quality 5. Safety
WL.17	Automated maintenance schedule generation based on equipment performance data	6	2, 5
WL.18	Automated scale-back of operations based on anomalous equipment performance data	6	2,5
WL.19	Actual/real-time schedule determination/assessment	--	--
WL.19.1	Job diaries/daily progress reports	4	3
WL.19.2	% physical complete tracking	4, 5, 6	3
WL.20	Field labor tracking	--	--
WL.20.1	Bar-coded worker ID's	4, 5, 6	3, 5
WL.20.2	Automated work-hour trending/projection	2, 4, 5, 6	3
WL.21	Heavy lift planning	--	--
WL.21.1	All manual	4, 6	Baseline
WL.21.2	Automated crane selection	4, 6	1
WL.21.3	Automated rigging design	4, 6	1
WL.21.4	Automated lift simulation	2, 4, 6	1, 5
WL.22	Operator training	--	--
WL.22.1	Manual approaches only	6	Baseline
WL.22.2	Simulation-based	6	1, 2, 4

Appendix H – Classification of Assessment Questions

Question ID	Description	Classification	
		Task	Integration Link
1.01	Conduct market analysis or need analysis for a new facility	X	
1.02	Develop, evaluate, and refine the project's scope of work	X	
1.03	Diagram the manufacturing process -or- the user's processes ("bubble diagram")	X	
1.04	Estimate a budget from the scope of work		X
1.05	Develop a milestone schedule from the scope of work		X
1.06	Acquire and store site investigation data for use during design		X
2.01	Designers access supplier information in order to select components		X
2.02	Get input from operators and builders regarding construction methods selection, & construction sequencing		X
2.03	Analyze alternative construction methods for effects on cost, schedule, etc.		X
2.04	Use conceptual design work as a basis for detailed design work		X
2.05	Generate facility floor plans	X	
2.06	Design the fluid transport system (open channel or pipes) and related drawings	X	
2.07	Design the structural system and related drawings	X	

Question ID	Description	Classification	
		Task	Integration Link
2.08	Design the electrical system and related drawings	X	
2.09	Design the HVAC system and prepare related drawings	X	
2.10	Document the assumptions used in developing the budget, and pass to the next phase		X
2.11	Detect physical interference between systems (i.e. plumbing, electrical, structural, etc.)		X
2.12	Prepare project specifications	X	
2.13	Check the design against owner requirements (e.g. design reviews) and code requirements		X
2.14	Track design progress	X	
3.01	Determine the lead time required to order equipment and materials		X
3.02	Conduct a quantity survey of drawings	X	
3.03	Link quantity survey data to the cost estimating process		X
3.04	Link supplier cost quotes to the cost estimating process		X
3.05	Refine the preliminary budget estimate	X	
3.06	Develop the milestone schedule	X	
3.07	Develop and transmit requests for proposal to suppliers and subs		X
3.08	Prepare & submit shop drawings		X
3.09	Acquire & review shop drawings; send response		X

Question ID	Description	Classification	
		Task	Integration Link
3.10	Compile quotes from suppliers & subs into a bid or proposal package		X
3.11	Monitor the progress of fabricators		X
3.12	Plan the transportation routes of large items from the fabricator to the job site	X	
4.01	Develop the construction schedule	X	
4.02	Track field work progress & labor cost code charges		X
4.03	Maintain a daily job diary	X	
4.04	Update the current cost forecast	X	
4.05	Keep all project team members up to date on construction progress		X
4.06	Track the inventory of materials on site		X
4.07	Link field material managers to suppliers		X
4.08	Develop short-term work schedules based on labor, equipment, and material availability	X	
4.09	Work crews submit and receive answers to Requests for Information (RFI's)		X
4.10	Builders provide feedback about the effects of design changes, made by owner or A/E, on cost and schedule		X
4.11	Communicate design changes to field personnel		X
4.12	Communicate status of change orders to field		X
4.13	Update as-built drawings		X

Question ID	Description	Classification	
		Task	Integration Link
4.14	Contractors submit requests for payment		X
4.15	Transfer funds from owner's account to contractor		X
5.01	Evaluate subsurface conditions	X	
5.02	Carry out earthwork and grading	X	
5.03	Construct rebar cages	X	
5.04	Weld pipes	X	
5.05	Select the appropriate crane for heavy lifts	X	
5.06	Provide an elevated work platform	X	
5.07	Fabricate roof trusses	X	
5.08	Manipulate and hang sheet rock	X	
5.09	Acquire & record laboratory test information		X
5.10	Finish concrete surfaces	X	
5.11	Apply paint or coatings	X	
6.01	Conduct pre-operations testing	X	
6.02	Train facility operators (e.g. simulations, software)	X	
6.03	Use as-built information in personnel training		X
6.04	Track & analyze the maintenance history of important equipment		X
6.05	Develop maintenance plans from maintenance history data		X
6.06	Monitor & assess equipment operations	X	

Question ID	Description	Classification	
		Task	Integration Link
6.07	Facility operators request maintenance or modifications		X
6.08	Update as-built drawings in response to facility modifications		X
6.09	Monitor/track/control facility energy usage		X
6.10	Monitor environmental impact of facility operations (e.g. air / water quality)		X

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Vita

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